Field Trip Guide
Carolina Geological Society
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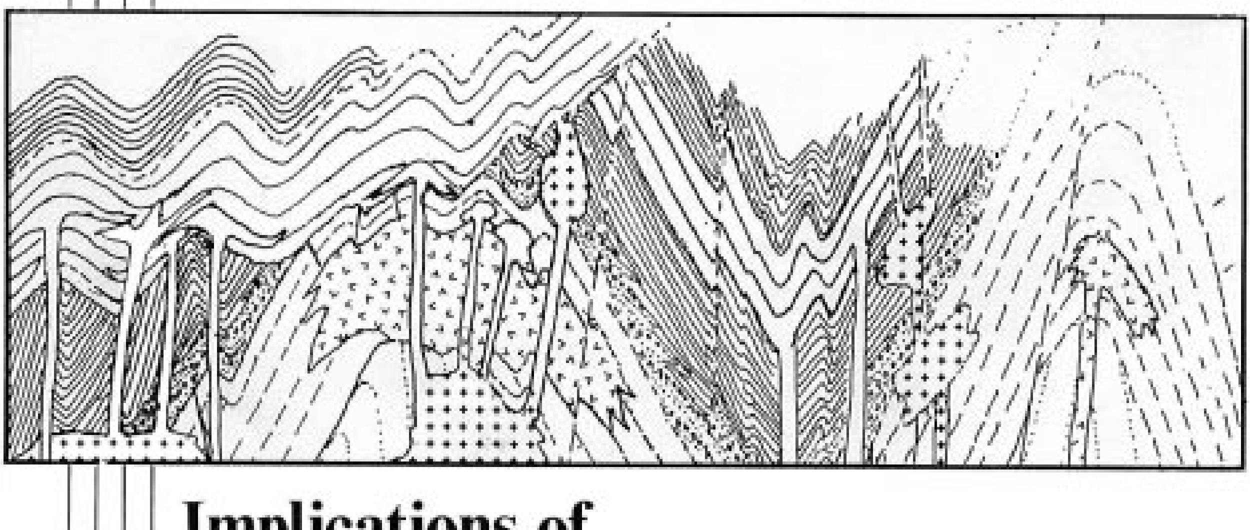
THE VIRGILINA DEFORMATION:



Implications of Stratigraphic Correlation in the Carolina Slate Belt

THE VIRGILINA DEFORMATION

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leaders:
Charles W. Harris, Lynn Glover, III

sponsored by:

Orogenic Studies Laboratory
Department of Geological Sciences
Virginia Tech, Blacksburg, Virginia
and
Virginia Division of Mineral Resources
Charlottesville, Virginia

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BRIEF STATEMENT OF PROBLEM

In 1973 Glover and Sinha proposed that an orogenic event, which they named the Virgilina deformation, was indicated by the geologic structure of the Virgilina-Roxboro area, Figure 1. The deformation occurred at about 600 Ma and resulted in regional folding and faulting of a sequence of Late Precambrian volcanic rocks of magmatic arc affinities. Since 1973 the Virgilina deformation has not been widely recognized outside of the type area. Additionally, confusion exists over: 1) stratigraphic criteria for correlating the slate belt between central — and northern-North Carolina, (Fig. 1), and 2) implications of the recent *Pteridinium* find for correlation between the two areas. During this field trip we will attempt to clarify the preceding points and to answer the following question:

Is the Virgilina deformation merely a local event? Or, is it a major regional event within the Carolina slate belt?

HISTORY OF THE CONTROVERSY

The present uncertainties probably began shortly after the 1973 paper because of speculation by Glover (1974) that the younger and more gently folded slate belt sequence (Uwharrie to Yadkin Formations) of the Albermarle area probably is unconformable (see Fig. 2) upon the older, more intensely deformed slate belt sequence represented by the rocks in the Roxboro-Virgilina area.

This interpretation was reinforced in Briggs et.al. (1978) with the determination that the (post Virgilina) Roxboro Metagranite was a very shallowly emplaced pluton belonging to a younger volcanic sequence. Briggs et.al. suggested that this younger volcanic sequence had been eroded from the Roxboro-Virgilina area but was still present in the Albemarle area of central North Carolina.

In a study of the chemical characteristics of the Carolina slate belt, Black (1980) accepted an unconformable relation (Virgilina deformation) between the younger and older slate belt sequence and pointed out that the younger sequence resembled an immature low-K tholeiite-bearing arc erupted through and deposited unconformably upon the deformed older calc-alkaline rocks. The immature nature of the younger sequence suggests the beginning of a new arc, transform, or pull apart basin and, we believe, supports the regional orogenic nature of the Virgilina deformation and its postulated unconformity.

Bland and Blackburn (1980) independently determined a calc-alkaline affinity for the older slate belt sequence. They found a weaker but still positive affinity (Ti/Zr) of the younger slate belt with low-K tholeiites. Two models were considered to explain the field relations: 1) the younger slate belt was tectonically emplaced upon the older during subduction-related collision (We find no evidence to support this kind of structural relation.), and 2) the younger, chemically immature volcanic slate belt was erupted through and deposited unconformably upon the older calc-alkaline slate belt as the result of a new cycle of arc volcanism. This model is consistent with that of Black (1980) and with our own in so far as it explains the Virgilina deformation and its unconformity.

A very thoughtful analysis by Wright and Seiders (1980) focused directly on the regional significance of the Virgilina deformation. Their field work and isotopic dating in the Albemarle area, when combined with the data and conclusions from the older volcanic sequence, yielded three hypothetical scenarios:

1. “The stratigraphic sequences of the two areas (i.e. Virgilina-Durham and Albemarle) are partly correlative. The Virgilina deformation was synchronous with deposition of the upper part of the central North Carolina sequence, but the deformation did not extend into the central North Carolina area.
2. The stratigraphic sequences of the two areas are correlative, and the Virgilina deformation was younger than the central North Carolina sequence but was weak or absent in that area.
3. The central North Carolina sequence is entirely younger than the Virgilina deformation, and the volcanic rocks may represent an extrusive phase of the plutonism of the Roxboro-Durham area.”

Interpretation #2 was rejected because it appeared to

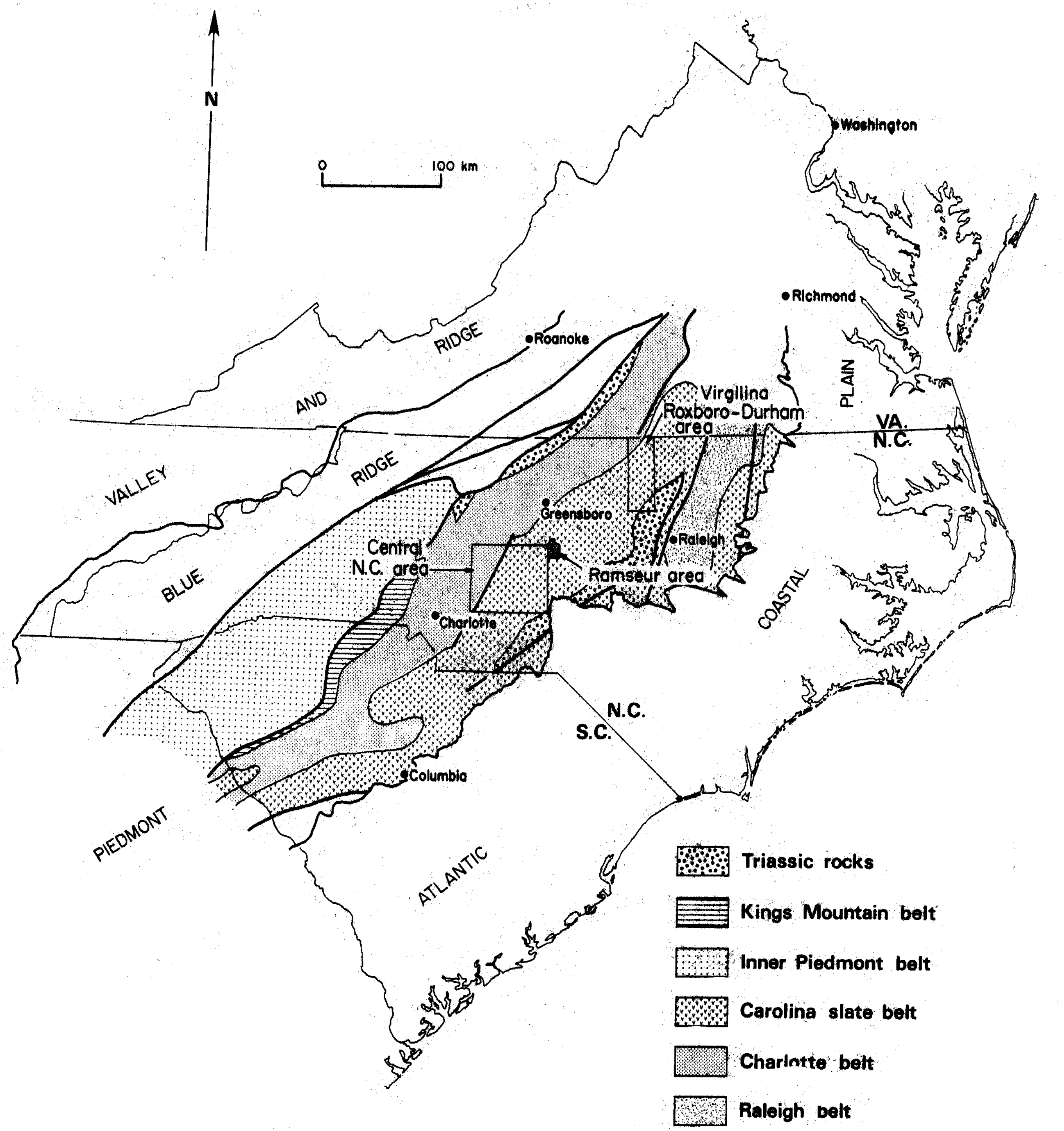


Figure 1: Regional geologic map of Virginia and the Carolinas showing the Carolina slate belt in relation to surrounding geologic belts of the Piedmont Province. Some areas of previous mapping are shown.

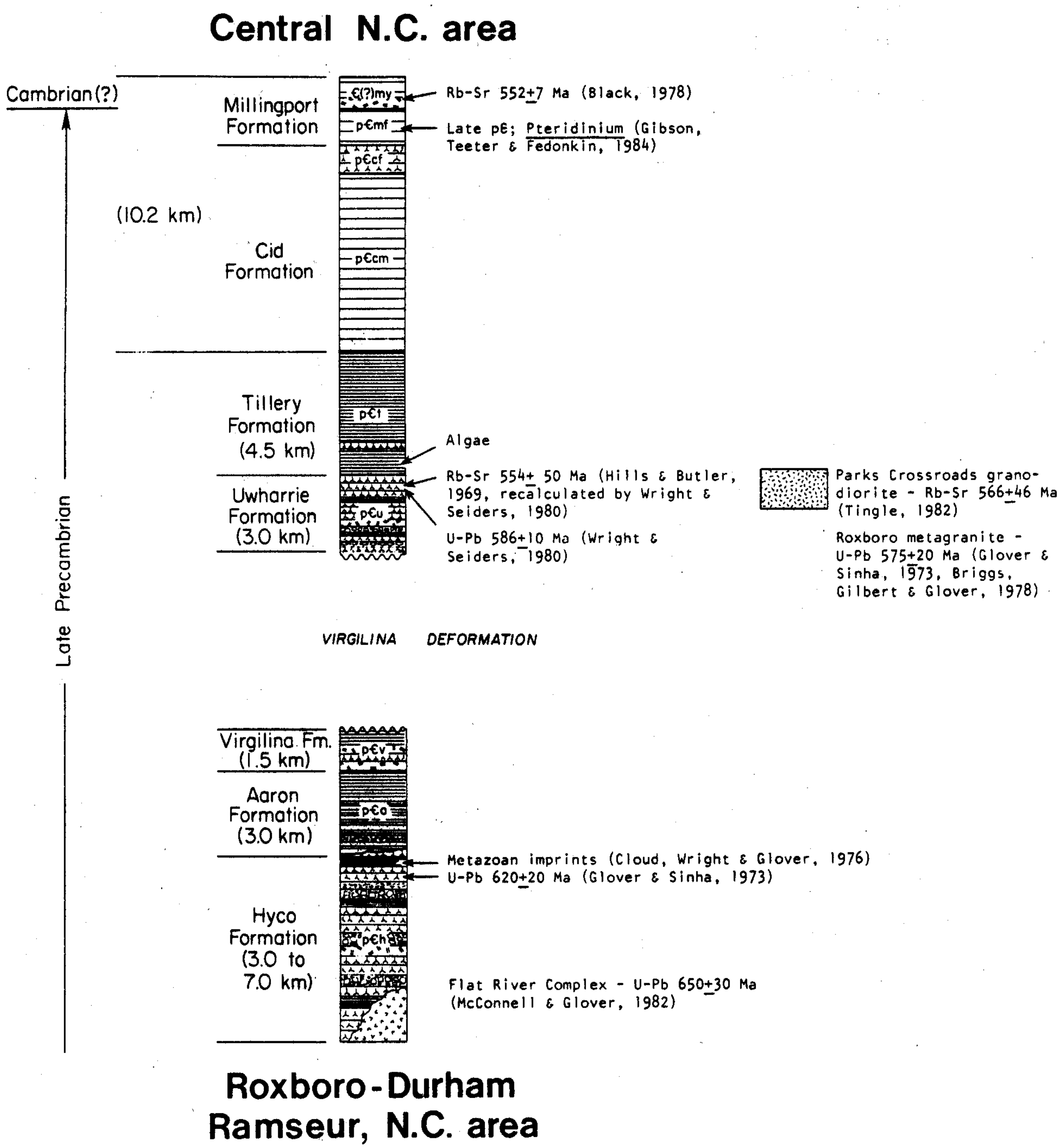


Figure 2: Stratigraphic column for the Carolina slate belt including stratigraphic units from Roxboro-Durham, Chapel Hill, N.C. area extending into central N.C. and incorporating recent work from Ramseur, N.C. area. (Compiled from Glover and Sinha, 1973; Cloud et al., 1976; Black, 1978; Briggs et al., 1978; Wright and Seiders, 1980; McConnell and Glover, 1982; Tingle, 1982; Harris, 1983; Gibson et al., 1984).

violate age constraints. Interpretation #3 conformed best to the isotopic age data but violated their belief that the Tillery Formation of the Albemarle area correlated with (as first proposed by Conley and Bain, 1965), and was originally continuous with, the Aaron Formation (Unit III of Glover and Sinha, 1973) of the Virgilina area. Thus Wright and Seiders chose interpretation #1 as the most likely, recognizing that all three models had serious defects. By this preferred interpretation the Virgilina deformation was considered synchronous with the sequence (Uwharrie through Yadkin Formations) in the Albemarle area and the deformation was merely a local event and did not extend into the Albemarle area.

The present field trip is organized, in part, to present evidence that the Tillery does not correlate with, but is younger than, the Aaron/Unit III and that the Virgilina unconformity occurs below the Uwharrie Formation. Thus our preferred model remains interpretation #3 as originally proposed by Glover (1974).

Rogers (1982) reviewed the petrological and geochemical literature of the Carolina slate belt in order to analyse the tectonic environments of formation for the better described localities. Stratigraphic relations in the slate belt were not within the scope of his study. However, his analyses of the tectonic environments reinforce the ideas of Black (1980) and Bland and Blackburn (1980) in that the younger sequence is considered more immature than the older calc-alkaline volcanics of the Chapel Hill and Virgilina areas. W interpret this to be consistent with the development of a younger magmatic arc, transform or pull-apart basin (Uwharrie to Yadkin sequence) unconformably upon the deformed remnants of an older magmatic arc (Hyco to Virgilina greenstone sequence).

In the Lincolnton, GA-McCormick, SC area, Carpenter and others (1982) correlated the Lincolnton Metadacite and overlying felsic pyroclastic formation along the Georgia-South Carolina line with the Uwharrie Formation of the Albemarle area in central North Carolina. This correlation was based on similar ages of the dacite and similar appearance of overlying banded argillites (i.e. Tillery argillite in NC, "upper sedimentary sequence" near Lincolnton, GA). In their discussion of regional relations Carpenter and others seem ambivalent about the nature of the contact between the older and younger slate belt sequences. On the one hand they state that their study (by amplifying the widespread distribution of the younger sequence?) implies that the Roxboro-Chapel Hill sequence is older and probably separated from the younger sequence by an unconformity (Virgilina deformation). On the other hand they state that "…we readily can accept Wright and Seiders' suggestion that the Virgilina deformation (Glover and Sinha, 1973) was a local disturbance…in the sense that the slate belt was an active orognene." Finally they state, "…perhaps it is unrealistic to attempt such lithostratigraphic correlations over large distances within volcanic arcs where similar stratigraphies associated with different volcanic centers need not be time equivalent." This last position seems inconsistent with the main thrust of their own paper, i.e., correlation of a specific lithostratigraphic sequence over a distance of 200 miles fro Lincolnton, GA to Albemarle, NC.

The general problem of attempting detailed stratigraphic correlation in volcanic terranes is difficult in near-vent areas but at a larger scale of observation is facilitated somewhat by a submarine environment of accumulation. This may be clearly seen in the detailed map of the dominantly submarine volcanic sequence of the Cretaceous and early Tertiary of southern Puerto Rico (Glover, 1971). The dominance of pyroclastic materials in submarine magmatic arcs, the effective distributional mechanisms (fall out, density current and gravitational transport) for pyroclastic and reworked clastic sediment, and the enhanced preservation potential of the deep water sequences, all work to impose a lateral stratigraphic continuity that may be regional in scope.

In the slate belt of the southeastern U.S. the deeper water turbidite bearing sequences are most likely to provide the stratigraphic continuity needed to tie together distant areas. We believe that the Aaron Formation/Unit III is likely to be the most obvious stratigraphic tie between Virgilina and central North Carolina.

According to Feiss (1982) syngenetic pyrrhotite- and galena-bearing massive sulfide and remobilized gold deposits of the Carolina slate belt in North Carolina and Virginia show an affinity for the quiet, generally deep marine western part of the belt, while the hydrothermally generated pyrophyllite deposits occur in the "subaerial to very shallow subaqueous" near vent regions of the eastern slate belt. His model apparently places the exhalative sources of the ore forming brines in the eastern "volcanic arc" belt with dominant accumulation in the western belt of "subsiding back arc basin" accumulation.

Current literature suggests that Feiss' eastern belt is dominantly marine (Glover and Sinha, 1973, Wright, 1974, McConnell and Glover, 1982, Harris, 1982, and Newton, 1983) probably deposited below storm wave base. This is based on a number of observations including general absence of shallow water or subaerial structures which are known to occur in only a few units of: 1) the upper part of the Hyco Formation in the Roxboro area, 2) map unit C in Chatham and Moore Counties in NC (Green et al., 1982), and 3) several units of the Hyco Formation in the Durham-Hillsboro area (Wright, 1974, Newton, 1983). In contrast there is the common occurrence of turbidites in nearly every other map unit. Sorting characteristics (separation of fine fraction) in submarine pyroclastic deposits require fall through a moderately deep column of water (Wright, 1974). It is worth noting that Feiss' eastern belt corresponds (excepting the Uwharrie) to the older Virgilina-Durha sequence. Obviously, the validity of the Virgilina deformation as a truly regional event separating these two sequences (assumed in Feiss' model to be coeval) by an unconformity is an important aspect in the interpretation of economic minerals genesis in the Carolina slate belt.

Harris (1982), in an unpublished M.S. thesis, presented the first field evidence for the occurrence of the Virgilina unconformity in central North Carolina. Along the eastern margin of the Uwharrie Formation in the Asheboro and Ramseur guadrangles Harris mapped formations identifiable as the Hyco and Aaron from the older sequence in the Virgilina area. Although the unconformable contact does not seem to crop out in the area, mapped structural and stratigraphic relations support the conclusion that the Uwharrie Formation unconformably overlies the more strongly deformed older sequence. Some of these results were published in an abstract by Harris and Glover (1982). During the first day of our field trip Harris will demonstrate much of the evidence leading to this conclusion.

PTERIDINIUM IN THE YOUNGER SEQUENCE

Gibson et al. (1984) described a remarkable occurrence of the metazoan *Pteridinium* from the upper Cid or lower Millingport Formations in Stanley County, NC. The new localities are near the site of an earlier fossil find reported (St. Jean, 1973) to possibly represent the trilobite *Paradoxides*, a Cambrian form. Re-evaluation of all of the fossils by Gibson and colleagues indicates that the specimens earlier thought to be trilobites belong to the genus *Pteridinium*. *Pteridinium* is known to be an Ediacarian faunal element, i.e., one of an assemblage of soft bodied metazoans that characterized life between 700 Ma and the first appearance of skeletal material at the beginning of the Cambrian. Estimates for the beginning of the Cambrian range from 550 Ma to 600 Ma and currently favor 570 Ma (Geological Society of America, DNAG 1983 Geologic Time Scale).

In Figure 2 our preferred stratigraphic sequence for the Carolina slate belt with isotopic ages and fossil occurrences is shown. If we take the isotopic ages at face value *Pteridinium* appears to be between 540 $\pm$ 7 Ma (Milton, 1984) and 554 $\pm$ 50 Ma based on Rb-Sr whole rock dates. However, by zircon U-Pb isotopic dating the Upper Uwharrie is 586 $\pm$ 10 Ma, about 30 m.y. older than the Rb-Sr age. Because of the high temperature of closure of the zircon lattice to migration of radiogenic daughter products and the resistance of zircon to subsequent alteration, zircon ages more nearly record actual crystallization ages. Rb-Sr ages on the other hand ideally record the time when the volcanic whole rock became a closed system to the migration of elements. Because volcanic rocks are highly unstable in near surface conditions they may experience mobility of constituents in diagenetic and low grade metamorphic environments during millions of years before they become closed to further major migration of radiogenic elements.

Therefore, we can expect Rb-Sr ages of volcanic lavas, plugs and pyroclastic rocks to be as much as 10 to 30 m.y. younger than their actual times of emplacement. The $\pm$ error values given with the ages are, of course, experimental error estimates and do not include the geological errors introduced by not being able to determine the interval of time between generation and emplacement of the volcanic rock and attainment of closed system conditions. By this reasoning the true age of the Yadkin Graywacke might be nearer 570 Ma instead of 552 Ma. If so, Pteridinium would be at home in Precambrian rocks.

Relative and chronologic ages are important aspects of the data base but they gain much more credence if they can be placed in a firm stratigraphic and structural framework. Stratigraphy and structure determined by geologic mapping will probably always remain the fundamental bases for understanding a complex of terranes such as the Piedmont. Thus, on this field trip we concentrate on physical stratigraphic and structural aspects of the Virgilina deformation between the type area on the Virginia-North Carolina line and central North Carolina, near Ramseur.

Our conclusions are graphically stated in Figure 2 and Figure 11 (in Appendix). The Virgilina deformation exists and appears to have produced an unconformity of regional extent in Virginia and the Carolinas. Cover by the younger sequence probably precludes finding it in the low grade belts south of central North Carolina though it may eventually be found in the higher grade Charlotte belt. Implications of the Virgilina deformation for tectonic models are beyond the scope of this guidebook. Some models have been presented in papers cited above; our own will be treated in future papers.

GEOLOGY OF THE RAMSEUR AREA

Introduction

Within the central North Carolina portion of the Carolina slate belt the Ramseur area (Fig. 1) represents a newly mapped terrane adjoining the Central N.C. area which has been examined in detail by Conley (1962); Conley and Bain (1965); Stromquist and Sundelius (1969); Seiders (1978, 1981); Wright and Seiders (1980); Goldsmith et al. (1982); Gibson and Teeter (1984); Gibson et al. (1984) and Milton (1984). Three distinct stratigraphic units are recognizable in the Ramseur area and include from oldest to youngest the Hyco, Aaron and Uwharrie Formations (Fig. 3). All units have been subjected to regional deformation and greenschist facies metamorphism, although relict igneous, pyroclastic and sedimentary structures are preserved throughout the sequence. The nomenclature for the stratigraphic units of the Hyco and Aaron Formation are comparable to Laney's (1917) Hyco Quartz Porphyry and Aaron Slate. The Virgilina greenstone is not exposed in the immediate area. A

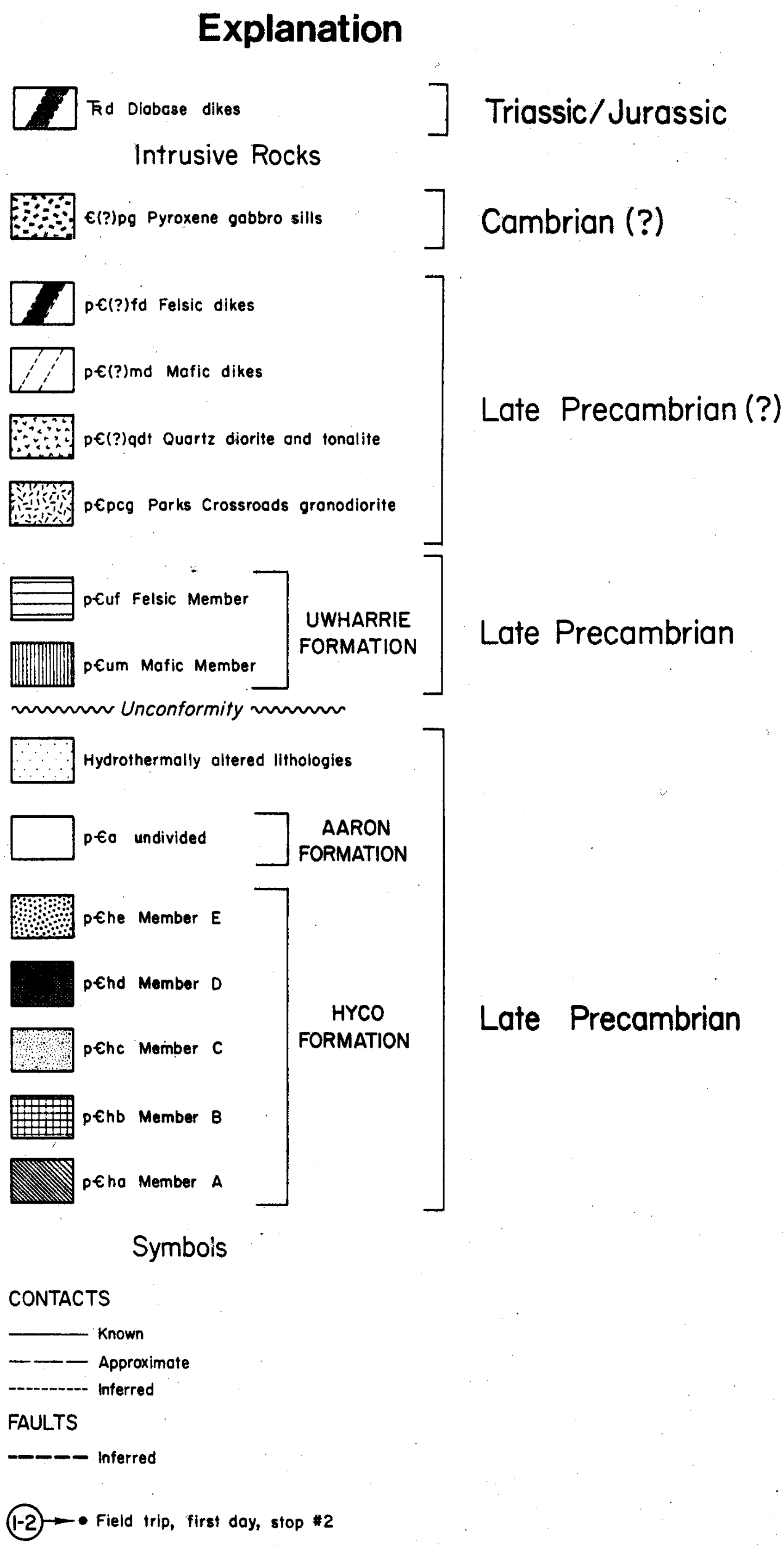
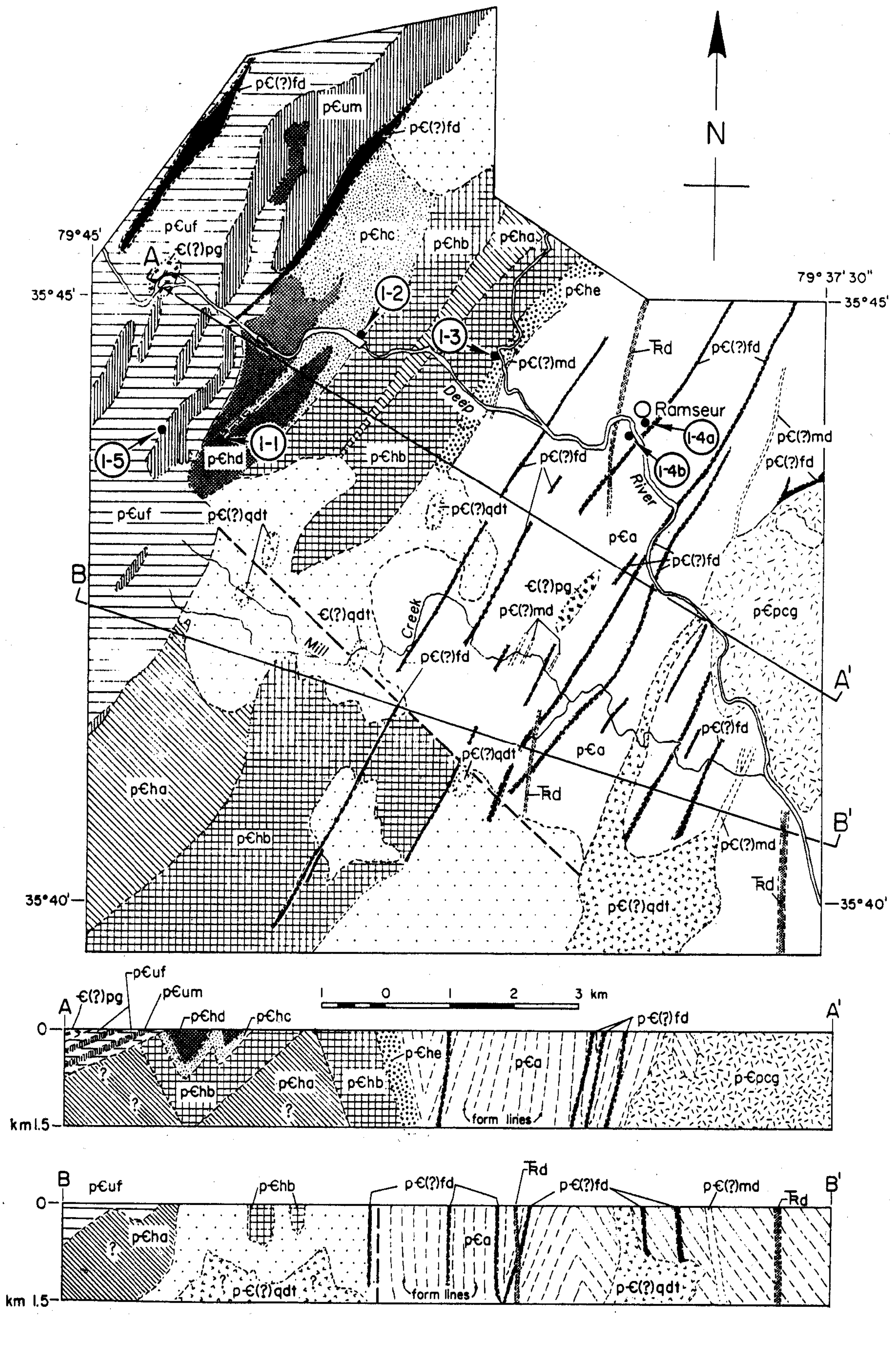


Figure 3: Geologic map of the Ramseur,N.C. area. Modified from Harris (1983).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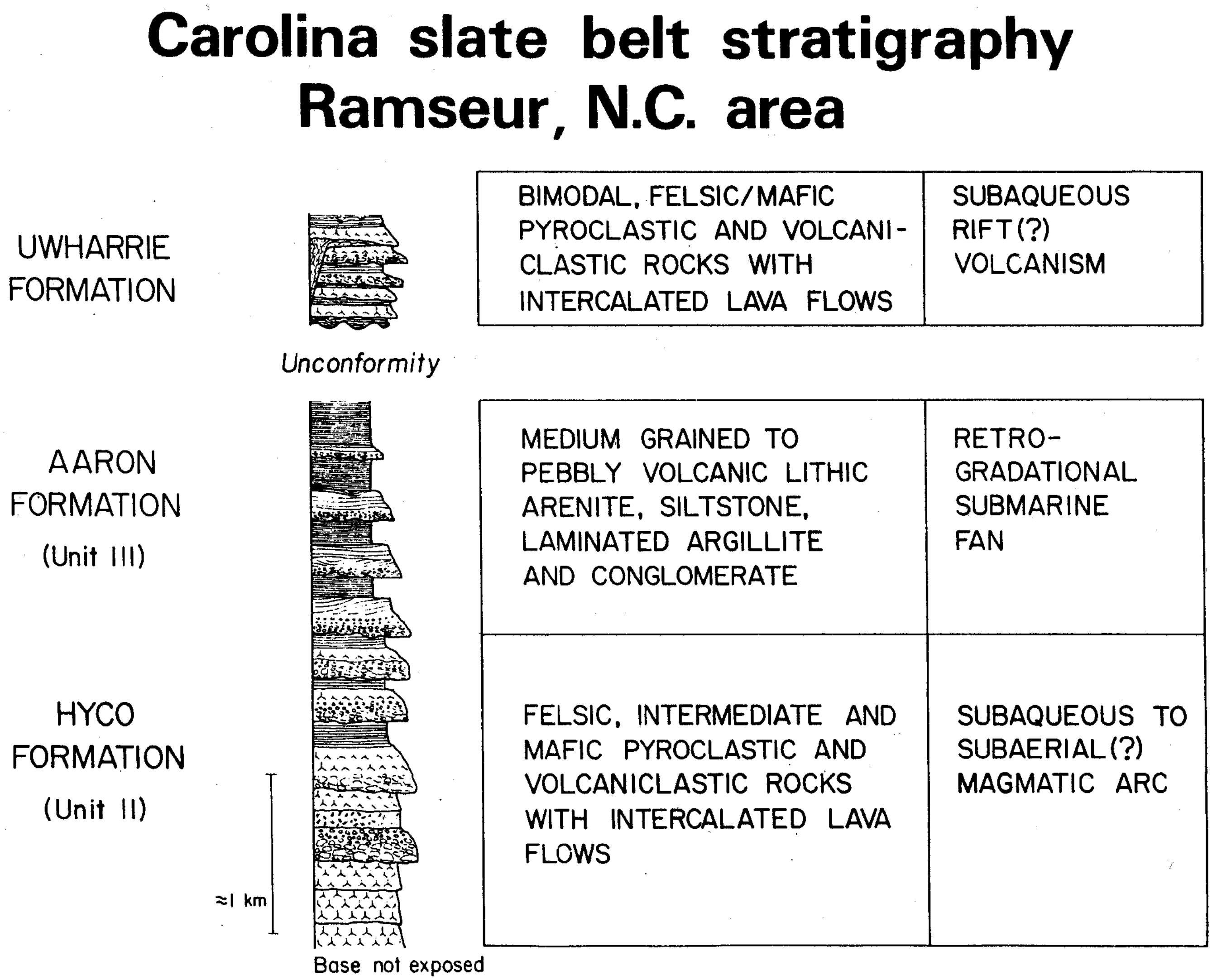


Figure 4: Simplified stratigraphic column for the Ramseur, N.C. area.

more detailed discussion of the history and origin of this nomenclature is provided in Harris (1982). The ensuing topical sections will review the stratigraphic and structural framework, intrusive rock relationships and metamorphism which were instrumental in correlating units of the Ramseur area with those in the Roxboro-Durham-Virgilina area. It is thus possible to recognize the effects and extent of the Virgilina deformation in this part of the Carolina slate belt.

Stratigraphy

Hyco Formation

The oldest exposed lithostratigraphic unit in the Ramseur area is the Hyco Formation (Figs. 3 and 4) which is subdivided into five members, A, B, C, D, and E with an aggregate thickness of 2 to 3 km. Members A, B, C and D comprise a sequence of intermediate pyroclastic/volcaniclastic rocks with intercalated lava flows. Pyroclastic units include tuff-breccias with a heterogeneous assemblage of angular to rounded clasts; i.e. porphyritic andesite and dacite, welded ash flow tuff, laminated tuff and plutonic clasts, granodiorite to tonalite, all of which are contained in a matrix of broken plagioclase and quartz crystals, pumice lapilli and ash. Size-grading in these units is not evident. Intercalated lapilli tuff, lapilli crystal tuff and lapillistone from massive to vaguely stratified thick-bedded units, which contain lithic fragments, vitriclasts and long tube pumice in a matrix of crystals and ash. Thin-bedded to laminated and rarely massive beds of crystal tuff and vitric tuff cap the coarse-grained pyroclastic units or are intercalated with intermediate to mafic lava flows. Interbedded vertical sequences of lapilli tuff, crystal tuff, and vitric tuff constitute doubly graded depositional units which may be up to 100 thick. Doubly graded units, as first defined by Fiske and Matsuda (1964), consist of a series of upward-fining thin beds deposited above a basal unit of lapilli tuff. Intemally, in this succession of thin beds, each bed is normally graded. It is inferred that the pyroclastic/volcaniclastic units were deposited in a subaqueous environment. Many of the pyroclastic units are similar to those described by Fiske (1963) and Fiske et al. (1963) in the Eocene Ohanepecosh Formation, Washington; by Fiske and Matsuda (1964) in the Miocene Tokiwa Formation, Japan; by Bond (1973) in the Pennsylvanian Delta River sequence, Alaska; by Niem (1977) in the Mississippian Stanley Group, Arkansas and Oklahoma; and by Fisher and Schminke (1984). Generally massive tuff-breccia is succeeded by lapilli tuff and lapillistone which is overlain by laminated vitric or crystal tuff. These depositional units are laterally extensive and can be traced for distances of 1 km or more. The basal tuff breccia is envisaged as the initial phreatomagmatic phase of eruption with vent clearing accompanied by the inclusion of abundant lithic debris in the eruption column. This is followed by the eruption of vesiculated glass (long tube pumice) and crystals from the magma chamber generating massive lapilli tuff. Waning fallout from the eruption column in conjunction with post eruptive quiescene results in a cap of thin-bedded to laminated vitric tuff and crystal tuff (Fiske, 1963; Bond, 1973; Niem, 1977; Fisher and Schminke, 1984). These deposits probably represent mass-flow units emanating from and slumping off the sides of a submarine volcanic center which might be analogous to high density turbulent suspension currents (Middleton and Hampton, 1973). The coarse-grain size of the tuff breccia (blocks is up to 1 m in size) suggests close to a vent site. Features suggestive of subaerial exposure and deposition; oxidized units, welding, extensive channeling, desiccation features, columnar jointing, and extreme lenticularity of units are not present in this portion of the Hyco Formation.

Porphyritic intermediate lava flows contain saussuritized and albitized plagioclase phenocrysts in an aphanitic blue-gray matrix, in this section a hyalopilitic to trachytic groundmass of plagioclase microlites surrounding plagioclase phenocrysts replaced by epidote + calcite + albite. Some flows are brecciated although pillows have not been recognized. Thin units of mafic lava are also present and contain quartz-filled amygdales <1 cm in diameter.

The uppermost portion of the Hyco Formation, Member E, marks a distinct transition to volcaniclastic breccias and/or conglomerates, arenites and tuffaceous mudstones with intercalated lapilli tuffs and crystal tuffs. A heterogeneous clast assemblage in the matrix-supported, massive to inverse-graded conglomerates includes intermediate porphyries, felsic-welded tuffs, intermediate pyroclastic rocks, vein quartz and granodiorite. These units in Member E are thought to represent sediment gravity flows equivalent to debris flows or lahars (Middleton and Hampton, 1973; Fisher and Schminke, 1984). The presence of medium-bedded, normally-graded stratified arenites and thin-bedded to laminated laterally extensive tuffaceous mudstones suggests deposition of these units adjacent to or in a subaqueous environment. In addition, the inclusion of clasts from several of the underlying volcanic units in the conglomerates suggests possible uplift and erosion of the former subaqueous volcanic province. Member E also demarcates the transition to the overlying epiclastic sediments of the Aaron Formation.

Aaron Formation

The Aaron Formation (Figs. 3 and 4) consists of approx 1.5 km of epiclastic sediments (detritus derived from previously consolidated rocks, cf. Fisher, 1966); conglomerate, lithic feldspathic arenite, siltstone, argillite and vitric tuff. Based on provenance studies, coarse-grained sediments of the Aaron are derived from erosion of the Hyco Formation, a magmatic arc terrane (Harris, 1984). A sedimentological analysis of the Aaron Formation indicates that sedimentation occurred in a deep-water setting with the overall sequence being analogous to a coarse-grained submarine fan model of Link and Nilsen (1979) (discussed in detail in Harris, 1984).

Within the Aaron Formation seven distinct facies are recognizable and include: 1) massive framework-supported conglomerate, 2) massive to stratified pebbly feldspathic arenite, 3) trough cross-bedded feldspathic arenite, 4) horizontally stratified arenite, 5) siltstone, 6) argillite and 7) vitric tuff. These facies comprise four facies associations A through D which are stacked in a sequence displaying an upward-fining and thinning of coarse beds.

Association A consists of upward-fining packages of facies 1, 2 and 5 in which the depositional units are tens of meters in thickness. Lithic conglomerates contain volcanic, plutonic and quartz arenite clasts in a matrix of crystals, silt and ripped-up clasts of siltstone. The conglomerates are gradationally overlain by massive to stratified pebbly lithic arenites which are capped by an abrupt transition to thin-bedded to laminated siltstones. The conglomerate to pebbly conglomerate units can be traced laterally for several hundred meters along strike as discontinuous outcrops. These depositional units are considered to be the product of high concentration turbulent suspension currents in which the upper part of the units are molded by tractive processes (cf. Middleton and Hampton, 1973; Walker, 1979; Hein, 1982). Residual suspension sedimentation from dilute turbidity currents accounts for deposition of the siltstones (Stow and Shanmugam, 1978). Association A may be analagous to the braided inner-fan channels of Walter and Mutti (1973), Normack (1978), Walker (1978) and Nilsen (1980).

Association B consists of composite upward-fining units of facies 2) pebbly arenites, 3) trough cross stratified arenites, 4) horizontally stratified arenites which grade upward into thin-bedded to laminated siltstone and argillite. Facies 2 contains ripped-up clasts of argillite and siltstone which are probably derived from erosion of underlying units. The presence of cross-stratification in facies 3 as well as stratification in facies 2 pebbly arenites suggests deposition of these units from concentrated turbulent high density suspension currents in which tractive processes were operative (cf. Hiscott and Middleton, 1979; Hein, 1982; Lowe, 1982). Horizontally stratified beds of facies 4 are thought to be produced by pulsating traction currents which mold sediment being deposited out of suspension (Lowe, 1982). Fluid was not retained in these units during deposition as indicated by the lack of dish structures, convolute layering and fluid escape pillars (cf. Middleton and Hampton, 1973; Walker, 1984). Facies 5 and 6, siltstones and argillites represent quiet water suspension deposition from dilute turbidity currents. Facies 2, 3 and 4 together are thought to represent braided mid-fan channels and may be the down fan equivalent of facies association A. Facies 5 and 6 are envisaged as interchannel or levee (?) deposits of the mid-fan channels which represent either overbank deposition or the residual sedimentation after channel abandonment.

Association C comprises coarse-grained to pebbly lithic arenite 2), grading vertically into horizontally stratified thin-bedded lithic and feldspathic arenite 4) capped by siltstone and argillite, 5 and 6). Intercalated vitric tuffs, 7) are also present. As in association B the transition from facies 2 to 4 indicates deposition of sediment from turbulent suspension currents in which tractive processes are operative. Facies 5, 6 and 7 represent residual background sedimentation during hiatuses between turbidity current deposition. Facies 7, vitric tuffs, may represent ashfalls into water from distant volcanic eruptions as well as distal depositional units from submarine volcanic eruptions. Facies 2 and 4 are interpreted as mid-fan depositional lobes because of the thinness of units (<2 m), and their infrequent recurrence in the vertical sequence. Intercalated, generally continuous sequences of facies 5, 6 and 7 suggest that pelagic and dilute turbidity current deposition was dominant during hiatuses in deposition of facies 2 and 4.

Association D includes minor coarse-grained to pebbly feldspathic arenite 2), siltstone 5), argillite 6) and vitric tuf 7). Facies 2 arenites are inferred to be the distal fallout of the previously described turbulent high concentration suspension currents in which tractive processes are still operative. Facies 5, 6 and 7 which are dominant in association D indicate that dilute turbidity currents and pelagic sedimentation were the prevailing mode of sedimentation. Facies 5 and 6 together are probably analogous to an incomplete Bouma sequence Tde beds. Facies 2 arenites may represent the margins of the coarse-grained depositional lobes of association C whereas facies 5, 6 and 7 are interpreted to be similar to basin-plain sediments described by Walker and Mutti (1973), Walter (1978) and Link and Nilsen (1979).

The vertical changes which occur in facies associations A to D suggest that the Aaron Formation is a retrogradational submarine-fan sequence. This is indicated by the vertical succession of braided inner-fan to mid-fan channelized deposits (associations A and B) to the suprafan lobes (association C) followed by basin plain sediments (association D). The basin plain sediments are thought to have formed marginal to the submarine-fan facies of association A, B and C. Sedimentation units in the Aaron Formation are coarse-grained, consistently upward-fining beds which are intercalated with siltstone and argillite. There is a rather abrupt transition from beds dominated by arenite to those composed of argillite, siltstone and vitric tuff. The above characteristics are similar to those described by Link and Nilsen (1979) for the coarse-grained submarine fan sequence of the Eocene Rocks Sandstone of California. The coarsening-upward outer fan cycles typically found in fine-grained fan systems (Walker and Mutti, 1973) are not present in the Aaron Formation. The abundance of coarse-grained sedimentation units suggests that the submarine-fan sequence of the Aaron Formation may be analogous to a “poorly efficient” (Mutti 1979, in Ricci Lucchi and Valmori, 1980) submarine-fan system.

In conclusion, the Aaron Formation sediments, based on petrographic and sedimentological data (Harris, 1984), were derived from erosion of a magmatic arc source (Hyco Formation) and were then deposited in a deep marine basin either marginal to or superimposed on the formerly active volcanic arc. The presence of plutonic clasts in the Aaron Formation records a significant dissection of the volcanic arc whereas the occurrence of quartz arenite clasts suggests that continental basement may underlie this terrane (Glover and Sinha, 1973).

Uwharrie Formation

The Uwharrie Formation (Figs. 3 and 4) in the Ramseur area is a less than 1 km thick bimodal volcanic sequence composed of felsic pyroclastic/volcaniclastic rocks and lavas with subordinate intercalated mafic pyroclastic rocks and amygdaloidal flows. From observed field relations the Uwharrie Formation unconformably overlies the Hyco Formation. The Uwharrie is Late Precambrian in age. Whole rock Rb-Sr data of Hills and Butler (1968) was later recalculated to an age of 554±50 Ma by Wright and Seiders (1980). U-Pb isotopic dating of zircons from felsic pyroclastic rocks in the upper part of the Uwharrie Formation yielded and age of 586±10 Ma (Wright and Seiders, 1980). For simplicity lithologies are subdivided into felsic and mafic members in the following discussion.

Uwharrie Felsic member

Felsic dacitic to rhyodacitic pyroclastic/volcaniclastic rocks include lapilli crystal tuff, tuff breccia, crystal tuff and vitric tuff which together form massive to stratified depositional units. Interbedded with or intrusive into the pyroclastic/volcaniclastic units are felsic, porphyritic to spherulitic flow-layered lavas.

Crystal tuff and vitric tuff beds are thin-bedded to laminated, horizontally stratified and rarely possess convolute laminae. Lithic-rich lapilli crystal tuffs and pumiceous lapilli crystal tuff form massive units up to tens of meters in thickness. Lithic crystal-rich units contain up to 60% broken plagioclase and quartz crystals with a subordinate component of lithic and vitric clasts. Pumice rich units contain flattened pumice fiamme which impart a pseudo-eutaxitic texture to the rock. However, evidence for welding in these units is lacking.

The felsic pyroclastic/volcaniclastic rocks were probably deposited in a subaqueous environment as indicated by the structures present in tuffaceous units and the absence of welding in pumice-rich units. Seiders and Wright (1977) recognized that doubly graded subaqueous pyroclastic flows do not occur in the Uwharrie Formation as substantiated in this study. Double grading may not occur due to the lack of an extensive water column to sort pyroclastic debris into separate size fractions (Fiske and Matsuda, 1964). Pumice constitutes only a small fraction of the Uwharrie pyroclastic units and is thought to be a product of either 1) the near complete crystallization of a shallow level eruptive magma chamber in which vesiculated glass is not produced or 2) the preferential removal of pumice and ash in an eruption column by elutriation or flotation with secondary enrichment of the crystal component by subaqueous phreatic explosions within the hot pyroclastic flow when it enters water (Cas, 1983). Lithic, vitric and crystal rich units in the Uwharrie resemble the mass-flow deposits described by Cas (1979), Cas et al. (1981) and Cas (1983) from the Lower Devonian Merrions Tuff and Kowmung volcaniclastics of Australia. These units are envisaged as being the products of high concentration density currents emanating from a subaqueous eruptive center or pyroclastic flows which enter into water (Cas, 1983; Fisher and Schminke, 1984). Intercalated laminated to thin-bedded tuffaceous rocks represent air falls of ash into water or residual deposition of the finer dilute fraction after passage of a high concentration density current.

Uwharrie mafic member

Mafic pyroclastic rocks include lapilli tuff, tuff breccia and vitric tuff. Associated with the pyroclastic units are amygdaloidal and pillowed lavas.

Repetitive sequences of pillow basalt, tuff-breccia, lapilli tuff and vitric tuff (<75 m thick) comprise the basal sequence of the mafic member in the Uwharrie Formation. Overlying this succession and interfingering with felsic lithologies are beds of mafic tuff breccia, lapilli tuff and vitric tuff. Mafic lapilli tuffs are commonly inverse graded and contain exotic outsize clasts of vitric tuff. These units are vaguely stratified to massive and grade upward into thin-bedded to cross stratified mafic vitric tuff. Rarely exposed in the Uwharrie are mafic tuff breccias which contain rounded to angular blocks (<0.5 m in size) of felsic porphyry, gabbro, laminated crystal tuff and felsic vitric tuff in a matrix of mafic lapilli.

Available evidence strongly indicates subaqueous deposition for the mafic rocks of the Uwharrie Formation. The vertical succession of pillow basalt, tuff breccia, lapilli tuff and vitric tuff is analogous to subaqueous basaltic units described by Carlisle (1963). During these hydroclastic eruptions (terminology of Fisher and Schminke, 1984) pillows and breccias are generated by slump, spalling and flow of pillows and matrix away from the vent site whereas lapilli tuff and tuff are the residual condensate from turbulent suspension currents accompanying the flow (Carlisle, 1963). Tuff breccias and lapilli tuffs are probably the result of phreatic to phreatomagmatic eruptions in which accidental material is expelled during the initiation of eruption followed by the explosive ejection of mafic lapilli and ash (Fisher and Schminke, 1984).

Intrusive Rocks

Intrusive rocks vary from mafic to felsic in composition and comprise dikes, sills, small stocks and plugs. These units are subdivided into two age groups Late Precambrian to Cambrian (?) and Triassic and/or Jurassic (Fig. 3). The Parks Crossroads biotite-hornblende (?) granodiorite (Tingle, 1982) is located in the eastern margin of the Ramseur area (Fig. 3), intrudes the Aaron Formation and is Cambrian (?) or Late Precambrian in age (566±46 Ma, Rb-Sr whole rock, Tingle, 1982). Contacts with the surrounding country rock are sharp although a silicified contact metamorphic (?) zone several hundred meters wide occurs on the margins of the granodiorite.

Mafic to felsic dikes <50 m wide are northeast trending (Fig. 3), laterally extensive and intrude the Hyco, Aaron and Uwharrie Formations. Felsic dikes are either porphyritic or flow-layered and rarely spherulitic. Phenocrysts consists of quartz, alkali-feldspar, biotite (?) and plagioclase which are contained in an aphanitic to glassy groundmass. Mafic dikes contain phenocrysts of plagioclase and pyroxene (pseudomorphed by actinolite) in an intersertal to hyalopilitic groundmass of glass and microlites, now heavily altered and retrograded due to metamorphism. Because the mafic and felsic dikes are not radiometrically dated it is uncertain if they are Cambrian or Late Precambrian in age. However all of the dikes possess greenschist facies mineral assemblages, thus they are older than the regional ca. 480 to 440 Ma Taconic metamorphism. In addition, the dikes crosscut fold limbs in the Hyco and Aaron Formations, thus indicating they postdate deformation of these units.

Associated and consanguineous (?) with extensive hydrothermal zones (Fig. 3) are small plugs of undated granodiorite, tonalite and quartz diorite. Several of these plugs are aligned along a northwest trending zone of hydrothermal alteration. Contacts with the surrounding altered volcanic lithologies are gradational.

Intruding both the Uwharrie and Aaron Formations are gabbro dikes and/or sills. These units are aligned semi-concordant to the regional strike of all units and extend laterally for hundreds of meters to kilometers. Relict plagioclase and pyroxene (?) are now retrograded and replaced by albite and actinolite. No age dates are available on the gabbros, although the presence of a retrograde metamorphic mineral assemblage indicates that they probably predate the regional metamorphism

Triassic/Jurassic diabase dikes are less than 30 m wide, trend almost due north and extend laterally for several kilometers.

Structure

Based on the map pattern and composition of stratigraphic units in the study area (Fig. 3 and Fig. 5a), a major discontinuity is interpreted to occur at the contact between the Hyco and Uwharrie Formations. East of this contact there is a dextral bend in the map units of the Hyco and Aaron Formations from N40E to N52E. Similarly zones of ductile deformation and hydrothermal alteration are localized east of this contact. Compositional differences include a polymodal (basalt, andesite and dacite) volcanic suite for the Hyco Formation versus a strongly bimodal (rhyodacite and basalt) suite for the Uwharrie Formation. In addition, felsic dikes in the Hyco and Aaron Formation are aligned parallel with and connected to consanguineous felsic eruptive centers of the Uwharrie Formation. These same dikes in map patter cross-cut fold limbs in the Aaron Formation (compare Fig. 3 and Fig. 5a). Finally an inferred northwest trending fault zone which offsets the Hyco and Aaron Formations could not be traced into the Uwharrie Formation. In the following paragraphs a more detailed review of the deformation chronology and associated structures is provided which indicates that polyphase deformation may have occurred in this portion of the Carolina slate belt.

Evidence for polyphase deformation in this portion of the Carolina slate belt is indicated by: 1) orientation of fold axes, 2) lineation patterns defined by cleavage-bedding intersections, 3) orientation of faults and 4) relative intensity of deformation. Inferred D_1 structures (Virgilina deformation) are confined to the Hyco and Aaron Formations, whereas D_2 structures are attributed to the ca. 480 Ma Taconic deformation (Kish et al., 1979; Glover et al., 1983). A description of the structural events is summarized in Table 1.

D_1 Virgilina deformation

The first structural episode is confined to the Hyco and Aaron Formations and is represented by folding and faulting of the older volcanic-sedimentary sequence.

F_1 Folds

Macroscopic F_1 folds (Fig. 5a) in the Hyco and Aaron Formations trend N40E to N52E, with a distinct dextral bend on the eastern edge of the map area. The northwest limbs of F_1 folds in the Aaron Formation are over-turned to the SE. Map scale folds are tight to close folds with interlimb angles <40^o. Inferred F_1 folds in the Ramseur area are on the northwest limb of a northeast striking regional synclinoriu reconnaissance mapped by Green et al. (1982) (Appendix I, Fig. 11).

Faults

An inferred northwest trending fault zone (Fig. 5a) offsets the Hyco and Aaron Formations, as well as truncating F_1 fold axes. The apparent displacement in the Hyco and Aaron Formations is not observed in the overlying Uwharrie Formation.

Taconic deformation

The Taconic deformation affects all stratigraphic units in the study area and postdates the Virgilina deformation. During this event there was an overprinting of earlier structures by the development of F_2 folds, an S_2 cleavage and regional greenschist facies metamorphism.

F_2 folds are macroscopic to mesoscopic and 1 to 2 km to m scale in wavelength. Within the Hyco and Aaron Formation, F_2 folds are oriented N20E to N40E, plunge gently NE and SW and are approximately axial planar to the cleavage S_2 (Domain IV, Fig. 5b, Note: B pole plots on S_2 plane). In the Uwharrie Formation F_2 Folds are oriented N25E to N35E, plunge gently NE and SW and are approximately axial planar to the cleavage S_2 (Domain IIIb, Fig. 5b).

S_2 Cleavage

The pervasive cleavage S_2 is developed in all lithologic units, strikes N35 to N44E (compare Domains I, II, IIIa, IV and V, Fig. 5b) and dips steeply NW or SE. The cleavage morphology varies from a widely-spaced stylolitic to closely-spaced anastomosing to continuous cleavage (terminology of Powell, 1979). The cleavage S_2 contoured on stereograms defines a weakly developed nearly vertical fan (Fig. 5b) although in mesoscopic folds a cleavage fan is not evident (Domain IVa and IVb, Note: S_2 cleavage maxima dips consistently NW). Mesoscopic and macroscopic F_2 folds in all units are approximately axial planar to the cleavage plane, S_2 (Domain IIIb and Iva, Fig. 5b, Note: B pole plots on cleavage S_2 whereas inferred F_1 folds in the Hyco and especially Aaron Formation are not (Domain V, Fig. 5b). Therefore, F_1 folds in the Aaron Formation may be transected folds (cf. Powell, 1974; Borradaile, 1978; Gray, 1981).

L_2 Lineation

An intersection lineation, L_2, can be derived graphically on a stereonet from the intersection of the $_0$ and S_2 planes on a given outcrop. L_2 plots from all units plunge gently NE and SW (Domain II and IIIa+IIIb, Fig. 5b). Within the Hyco and Aaron Formations, L_2 also plunges steeply W and SW (Domain II, Fig. 5b). Because the lineation should approximate the orientation of a fold axis, one might expect to find

Table I: Chronology of structures and deformation events in the Ramseur area.

DEFORMATION	FOLD GENERATION, TYPE AND ORIENTATION	WAVELENGTH (estimated)	TECTONIC FABRIC AND ORIENTATION	FAULTING	DUCTILE DEFORMATION ZONES (DDZ)	UNITS AFFECTED
D_1 Virgilina deformation (ca. 600 Ma, Glover and Sinha, 1973)	F_1 tight to close folds; approximate axial trace. Orientation N 40 to 52 E; axial planes overturned to NW or SE	2 to 3 km	None	Reverse and/or Lateral wrench faulting	None	Hyco and Aaron Formations
D_2 Taconic Formation (Ca. 480 – 440 Ma, Kish and others, 1979)	F_2 close to open folds; approximate Axial trace orientation N 20 to 40 E; axial planes upright or overturned to SE; also as inferred second order folds on limbs of larger F_1 and F_2 folds.	Variable: Macroscopic 1 to 2 km Mesoscopic 3 m to 20 cm	S_2 cleavage Orientation N 35 To 45 E with Dominant steep, >75^{o} NW dip. Cleavage type- Spaced anastamosing disjunctive to Continuous rough or smooth.	Possible high Angle reverse faults related to DDZ's.	Localized zones of extensive shortening, attenuation and recrystallisation of volcanic rock units associated with pre-existing hydrothermal alternation zones. Orientation N 30 to 40 E Dimensions Width: 100 m to 1 km Length: Max –3 km	Hyco, Aaron and Uwharrie Formations
Late D_2 (?)			S_3 (?) crenulated and Microfolded S_2 localized in Ductile deformation zones.			Hyco and Aaron Formations
Post D_2: Mesozoic to Recent (?)	None	___________	None	Mesozoic Age extensional faulting facilitating the intrusion of diabase dikes. Recent (?) brittle faulting of deeply weathered units.	None	Hyco, Aaron and Uwharrie Formations

folds with this orientation in the Hyco and Aaron Formations, however none have been observed. Steeply plunging lineation are not present in the Uwharrie Formation (Domain IIIa + IIIb, Fig. 5b). It is thus plausible that the steeply plunging lineation, L_2, in the Aaron and Hyco Formations is related to fold transection and that the S_2 fabric is superimposed on pre-existing structural features which were generated during D_1; the Virgilina deformation.

Structural Summary

The orientation of structural features and fabrics in the Ramseur area suggests that two discrete deformation events may have occurred in this portion of the Carolina slate belt. Early developed folds in the Hyco and Aaron Formations were later deformed and overprinted by a second event which results in fold tightening and cleavage development. However the difficulty in separating two generations of structural fabrics in this area could be attributed to two nearly coaxial, though slightly oblique deformations. The present structural fabric could be explained alternatively by a continuous progressive deformation in which there is an overall reorientation of the stress field through time. However because of the stratigraphic data base, the first scenario is the preferred solution.

Metamorphism

All rocks units within the Asheboro-Ramseur, N. C. area

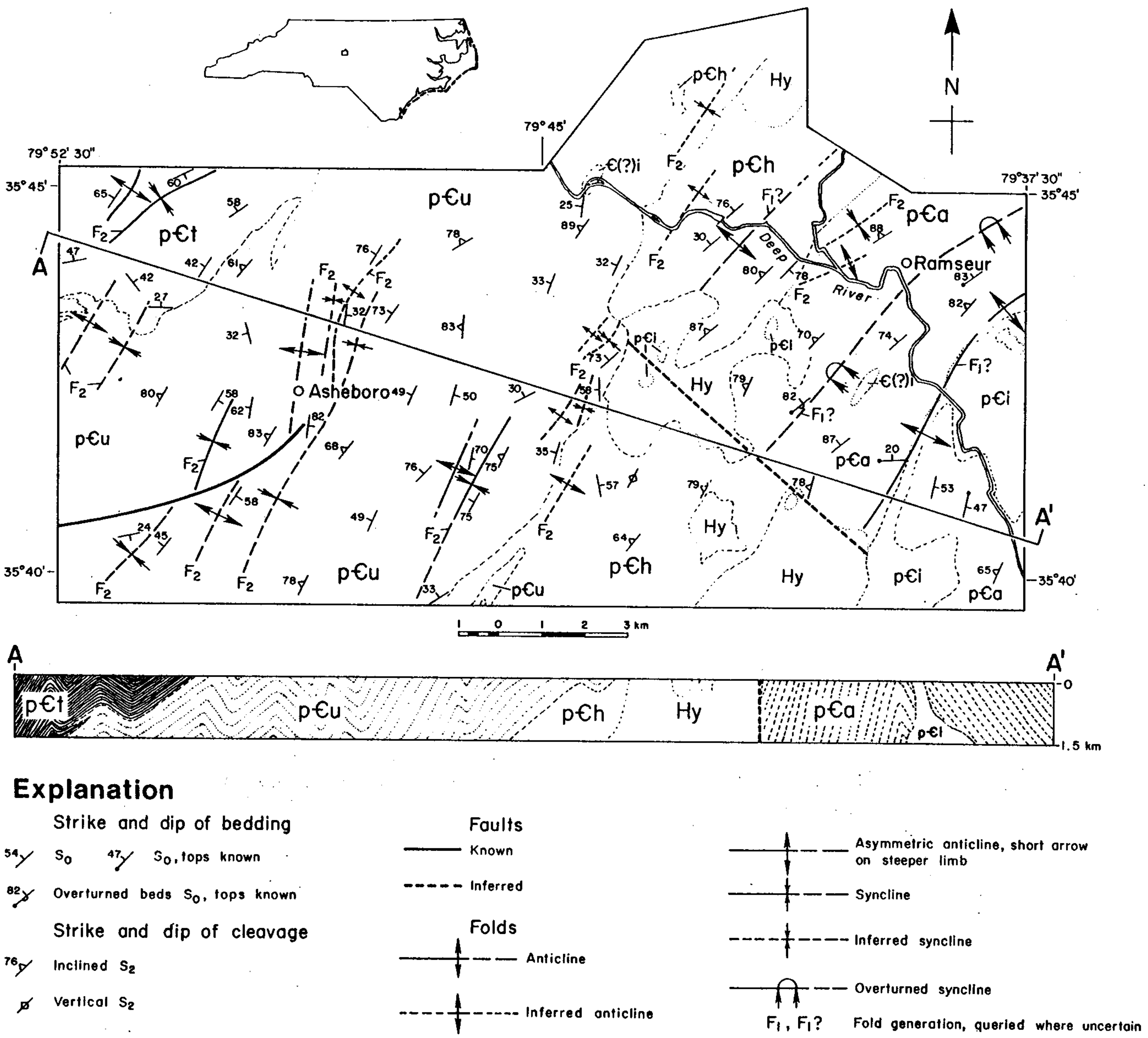
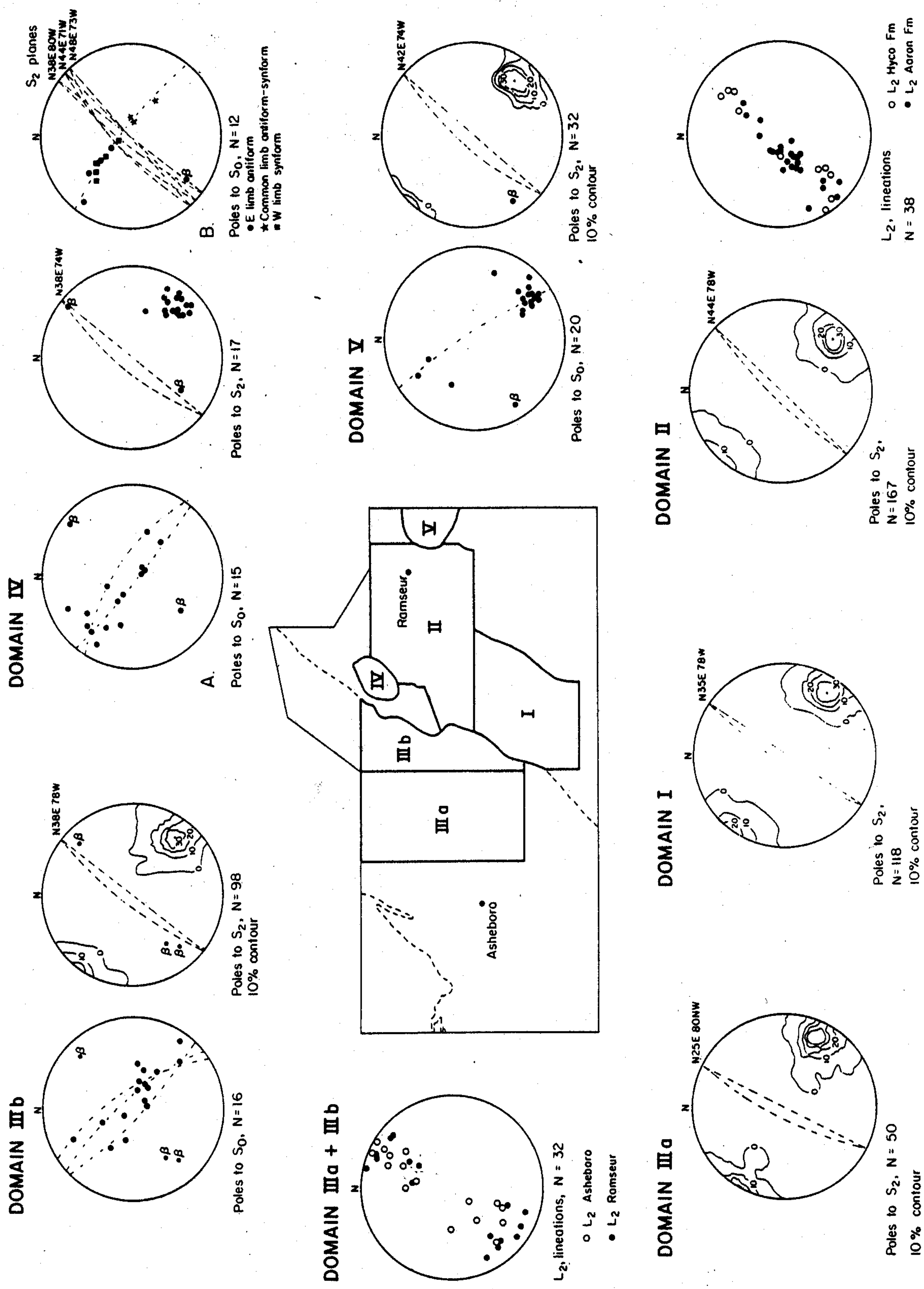


Figure 5a: Structural geology of Ramseur and Asheboro, N.C. area. Data for Asheboro from Seiders (19810



DOMAIN IIIb
Poles to S_0, N=16
N38E 78W
Poles to S_2, N=98
10% contour
DOMAIN IV
A. Poles to S_0, N=15
N38E 74W
Poles to S_2, N=17
S_2 planes
N38E 80W
N44E 71W
N48E 73W
B. Poles to S_0, N=12
• E limb antiform
★ Common limb antiform-synform
■ W limb synform
DOMAIN IIIa + IIIb
L_2, lineations, N = 32
○ L_2 Asheboro
• L_2 Ramseur
Asheboro
Ramseur
DOMAIN V
Poles to S_0, N=20
N42E 74W
Poles to S_2, N=32
10% contour
DOMAIN IIIa
N25E 80NW
Poles to S_2, N=50
10% contour
DOMAIN I
N35E 78W
Poles to S_2,
N=118
10% contour
DOMAIN II
N44E 78W
Poles to S_2,
N=167
10% contour
L_2, lineations
N = 38
○ L_2 Hyco Fm
• L_2 Aaron Fm

have been metamorphosed to greenschist facies up to the level of the biotite isograd. The metamorphism has primarily resulted in retrogression and replacement of the original igneous mineral assemblages. Lithologies confined to hydrothermal zones do not appear to be extensively re-equilibrated because of their highly aluminous composition, e.g. andalusite, pyrophyllite, topaz and diaspore (Schmidt, 1982; Harris 1982). However Sykes and Moody (1978) concluded that the mineral assemblage present in one of these zones (Hillsborough, N.C. area) was a product of the regional prograde metamorphism. Examples of retrogression include: albitization and saussuritization of calcic plagioclase and chloritization of mafic minerals and glass. Pseudomorphing of mafic minerals by chlorite and actinolite is also common. Cleavage fabrics consist of aligned chlorite, white mica and biotite. Thermal recrystallization in a static regime is indicated by the random growth of biotite porphyroblasts in pelites, strain free polygonized aggregates of quartz, and the random growth of epidote, actinolite and chlorite in intermediate to mafic volcanic rocks.

Post Taconic retrogression of metamorphic minerals is indicated in several rock types by the replacement of biotite by chlorite, especially along the margins and cleavage lamellae of individual crystals. These features may be due to a later regional metamorphic event as suggested by Briggs et al. (1978) who similarly observed retrogressive metamorphic mineral assemblages in the Roxboro metagranite.

The timing of metamorphism is uncertain in the immediate study area because no mineral isotopic age dating has been performed. As alluded to earlier, based on the work of Black (1977) and Kish et al. (1979), metamorphism probably occurred around ca 480 Ma and was regional in extent within the Carolina slate belt.

Summary of Virgilina Deformation in the Ramseu Area

Within the Ramseur area lithostratigraphic units have been identified which are strikingly similar to and thus probably correlative with those rocks of the Roxboro-Durham-Virgilina area. The Hyco Formation consists of mafic, intermediate and felsic pyroclastic/volcaniclastic and effusive rocks which are overlain by the epiclastic sediments of the Aaron Formation. Petrographic studies of the Aaron Formation indicate derivation of this unit from erosion of the Hyco Formation and an enigmatic continental source (quartz arenite clasts). A detrital component derived from the Uwharrie Formation is not recognizable in the Aaron. In addition, the Hyco Formation contains a nonvolcanic component of plutonic rock and quartz arenite. The timing of the ensuing hydrothermal alteration and associated plutonism are uncertain but may precede or be synchronous with the Virgilina deformation. Erosion of the Hyco and Aaron Formation is then followed by plutonism (Roxboro metagranite and Parks Crossroads granodiorite) and effusive volcanism of the Uwharrie Formation. The current work in the study area in conjunction with field relationships and structural data indicates that the Uwharrie Formation unconformably overlies the Hyco Formation and likewise the Aaron Formation. In addition the presence of cross-cutting dikes and younger plutons reinforces this interpretation. Faulting might be a compelling alternative to explain the existing discontinuity, although no major faults or laterally extensive ductile deformation zones have been located in this area. In addition major fault zones or detachment surfaces are not typical of the style of deformation in this low grade portion of the slate belt.

FIELD TRIP STOPS IN THE RAMSEUR AREA, DAY 1

U.S. 64-N.C. 49. Turn onto S.R. 2223 (dead end road) and continue to end of road. Outcrops of the Hyco Formation are exposed in small pasture behind the small barn and residence of Raeford Cox.

Stop 1-1 At this locality Member D of the Hyco Formation consists of intercalated unites of massive lapilli tuff and thin-bedded to laminated graded beds of crystal tuff and vitric tuff. The intermediate composition lapilli tuffs contain a subrounded to subangular heterolithic clast assemblage of plutonic and volcanic detritus and rare clasts of quartz arenite. The clasts are contained in a matrix of broken plagioclase crystals, ash and pumice lapilli. The lapilli tuffs are capped by graded units of thin-bedded, internally laminated crystal tuff and vitric tuff. The composite units are interpreted as the depositional products of explosive submarine phreatomagmatic eruptions which generated subaqueous pyroclastic flows (cf. Fiske, 1963; Fiske et al., 1963; Fiske and Matsuda, 1964; Fisher and Schminke, 1984). This is inferred from: 1) the poor sorting of units, 2) the lateral extent of depositional units (hundreds of meters to kilometers), 3) the presence of massive tuff breccia and lapilli tuff capped by laminated tuffaceous mudstones, 4) lack of welding in the flow units, 5) the abundance of broken crystals and lithic fragments and 6) the common occurrence of long tube pumice lapilli in these deposits (cf. Fiske, 1969).

The graded units of the Hyco Formation define a tight short wavelength fold, whose axial plane dips steeply northwest and in which bedding is overturned to the southeast. Mafic and felsic lithologies comprising the Uwharrie Formation 100 to 500 m to the west dip gently northwest, are upright and therefore overly the Hyco Formation. The current detailed data base indicates that the Uwharrie Formation unconformably overlies the Hyco Formation (refer to previous discus-

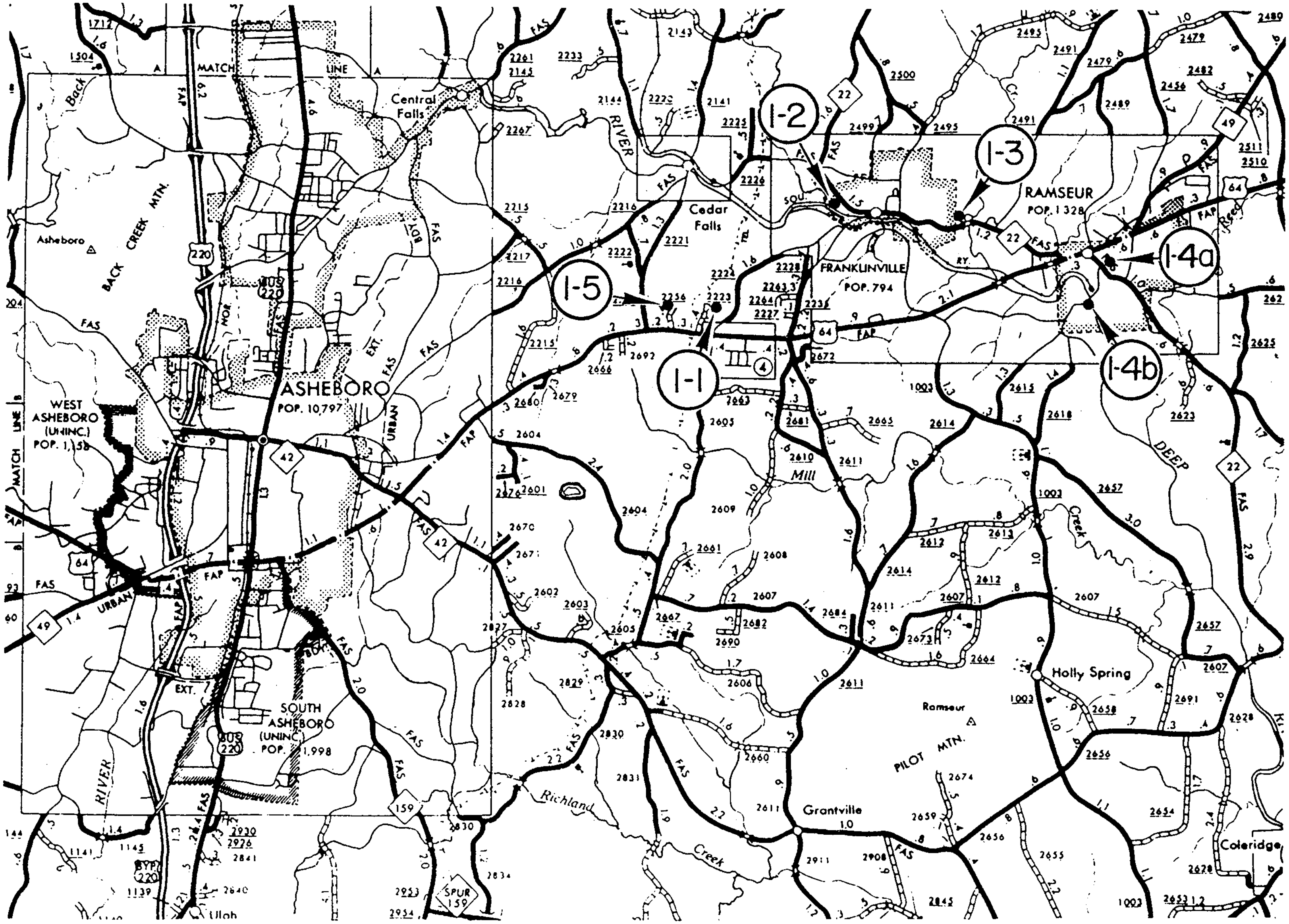


Figure 6: Field trip stops in Ramseur area. Distances are given in miles. Randolph County Road Map (1980), N.C. Department of Transportation, Division of Highways — Planning and Research Branch.

sion of stratigraphy and structure of the Ramseur area for further explanation). The Hyco is correlative with the intermediate lithologies to the north and northeast extending into the Roxboro-Durham, N.C. and South Boston, Va. areas.

Return to U.S. 64-N. C. 49, proceed east (turn left) 0.2 mi to intersection with S.R. 2224. Turn left at intersection and continue northeast on S.R. 2224 to jct. With S.R. 2235. Turn left, and continue north on S.R. 2235 (cross the Deep River) into the Town of Franklinville and to jct. with N.C. 22. Turn left and proceed west on N.C. 22 for 0.75 mi. to Methodist Church Cemetery on the left. Take gravel drive into rear of cemetery and park here. Outcrops of a felsic unit in the Hyco Formation are exposed as ledges in the rear of the cemetery, along a trail leading to the Deep River, in an abandoned railroad grade adjacent to the Deep River and immediately to the west in the streambed of Bush Creek.

Stop 1-2. Member C of the Hyco Formation at this stop consists of felsic (dacitic) tuff-breccia overlain by massive lapilli tuff and medium-to thin-bedded, internally laminated, lapilli crystal tuff and vitric tuff. The repetitive sequence of thin beds above the basal thick, massive beds of lapilli tuff are interpreted to be doubly graded pyroclastic flow units (cf. Fiske and Matsuda, 1964; see discussion of doubly graded depositional units in section on stratigraphy of the Hyco Formation in the Ramseur area).

The tuff-breccias are composed of subangular blocks of welded (?) ash flow tuff (0.5 to 1.0 m in size) in a matrix of broken plagioclase and quartz crystals and vitric lapilli. A similar unit just north of this locality contains lithic and pumiceous clasts in a matrix of plagioclase and magnetite crystals. The large clast size of the breccias suggests close proximity to a subaqueous vent site. Pyroclastic breccias are present in the Hyco Formation in the Ramseur, Chapel Hill (Hauck, 1977), Durham and Hillsborough (Wright, 1974; Newton, 1983), N.C. areas.

Return to N.C. 22, turn right and proceed east on N.C. 22 through Franklinville, N.C. for approx. 0.8 miles to Sandy Creek. Extensive outcrops exposed in and along the Deep River enroute to Stop 3 consist of intermediate lava flows and pyroclastic units, tuff breccias and lapilli tuffs. Outcrops of Member E of the Hyco Formation are exposed on V. McCorquadale's property as ledges on the west side of Sandy Creek, directly across from the water filtration plant for the town of Ramseur.

Stop 1-3. Lithologies exposed at this locality include massive to graded volcaniclastic conglomerates and/or breccias, thin-to medium-bedded lithic feldspathic arenites and/or lapilli crystal tuffs and intercalated tuffaceous mudstones. The polymictic conglomerates contain a clast assemblage of porphyritic dacite, andesite and basalt, intermediate crystal tuff, granodiorite, tonalite, welded ash-flow tuff, vein quartz and red chert. The clasts from an intact to floating framework and are surrounded by a matrix of vitriclasts, long tube pumice lapilli (?) or scoria, ash, plagioclase, quartz and magnetite crystals. The volcaniclastic conglomerates and/or breccias are interpreted as debris flows or lahars (?) because of their massive structureless nature and the inclusion of large clasts (<15 cm in size) floating in a coarse-grained matrix (cf. Middleton and Hampton, 1973; Fisher and Schminke, 1984). Deposition of these units may have occurred as a function of slumping and gravity flow of material off a subaerial or subaqueous volcanic edifice. Movement may have been triggered by explosive eruptions or earthquakes. The lapilli crystal tuffs and lithic feldspathic arenites are envisaged as being the product of turbulent high concentration sediment gravity flows (cf. Middleton and Hampton, 1973; Lowe, 1982) associated with the debris flows. The thin-to medium-bedded units may record residual sedimentation in which tractive processes were operative (Hiscott and Middleton, 1979; Hein, 1982; Lowe, 1982). Tuffaceous mudstones are thought to be the product of suspension sedimentation in a relatively quiet, low energy environment. The wide variety of clast types present may be the product of either 1) vent mixing of exotic clasts plus entrainment in a mass flow unit or 2) uplift and erosion of the former subaqueous volcanic province with transport of material by mass flow processes. The latter point is suggested because of the great variation in clast types as well as the position of this unit immediately below the Aaron Formation.

The volcaniclastic conglomerates are interpreted as debris flows whereas the lapilli crystal tuffs/feldspathic arenites are the product of high concentration sediment gravity flows. The tuffaceous siltstones and mudstones represent background suspension sedimentation.

Similar lithologic units have been described by Bain (1964), Conley and Bain, (1965; Denny Conglomerate Member), Glover and Sinha (1973), Wright (1974), Kreisa (1980) and Newton (1983). These conglomerates occur near the top of the Hyco Formation and are transitional to the overlying sediments of the Aaron Formation.

Continue east on N.C. 22 until junction with U.S. 64-N.C. 49 in Ramseur, N.C. Turn left, east, on U.S. 64-N.C.49 and proceed approx. 0.25 miles to Main St. Turn right onto Main St. and continue southeast on Main St. to Coleridge Road. Turn left off of Coleridge Rd. onto Liberty St. Outcrops of Aaron Formation are exposed in the yard behind F. Nelson's residence.

Stop 1-4a. The Aaron Formation at this stop consists of two facies: 1) thin-to medium-bedded, arenites and stratified arenites 4) and stratified to graded pebbly feldspathic arenites 2). These facies are interpreted to have been deposited in a deep water setting with sediment being distributed and deposited via a coarse-grained submarine fan system. Depositional units here are analogous to the S2 division of Lowe (1982), which are traction deposits of a high density concentrated turbulent suspension current. Clast types present in the arenites include felsic to intermediate lavas and pyroclastic rocks. At other locations in the immediate area, conglomerates in the Aaron Formation contain quartz arenite and plutonic clasts. The coarse-grained depositional units are inferred to represent mid-fan channels.

Retrace route to Main St. (Liberty St. to Coleridge Road to Main St.). Turn left, southwest, onto Main St. Go through town of Ramseur and turn right, west, onto Brooklyn Avenue. Park on either side of Brooklyn Ave. (pullouts on both sides) before crossing bridge over Deep River. Disembark from vehicles and walk across bridge to outcrops of Aaron Formation on the left, south side of bridge.

Stop 1-4b. Three facies of the Aaron Formation are present and include: 1) massive, pebbly feldspathic arenites, 2) horizontally stratified to parallel laminated lithic and feldspathic arenites and 3) laminated to thin-bedded siltstones. Composite units of pebbly and feldspathic arenites are 1 to 3 m thick and form large-scale upward-fining sequences with erosive bases. Sediment deposition was from concentrated turbulent suspension currents in which tractive processes were operative. These depositional units are analogous to the S1 to S2 divisions of Lowe (1982) and are capped by Bouma (1962) Tb beds. Siltstones are the product of residual suspension sedimentation from dilute turbidity currents and are equivalent to Td and Te beds. The coarse-grained depositional units are inferred to be transitional from braided mid-fan channels to suprafan depositional lobes. The siltstones represent either overbank (levees) or inter-channel, inter-lobe deposits (Walter and Mutti, 1973; Walter, 1978, 1984).

Retrace route north from Brooklyn Avenue to Main St. to U.S. 64-N.C. 49. Turn left, west, at jct. with U.S. 64-N.C. 49 and proceed west for approx. 3 miles to dead end gravel road, S.R. 2256. Turn right on S.R. 2256 and continue north for approx. 0.2 mi. to the first road on the left which crosses pastures (property of J. Pugh). Exit vehicles here and cross pasture to first outcrop immediately to the west. Units exposed here and nearby are part of the Uwharrie Formation.

Stop 1-5. The Uwharrie Formation consists of mafic lapilli tuffs, tuff-breccias, felsic (rhyolitic to rhyodacitic) lava flows and lithic, vitric lapilli crystal tuffs. The Uwharrie is compositionally bimodal and lacks the intermediate component typical of the Hyco Formation.

Mafic lapilli tuffs and felsic spherulitic flow-layered lavas are present in these first outcrops. Mafic lapilli tuffs posses gray-green subrounded to subangular lapilli (1-5 cm in dimension) which form crudely inverse to normally graded thick beds. Outsize clasts (15-20 cm max. dimension) of felsic laminated tuff are contained in these mafic pyroclastic units. The mafic lapilli tuffs are interpreted to be the products of basaltic subaqueous phreato-magmatic/hydroclastic eruptions (cf. Fisher and Schminke, 1984). Approximately 2 to 3 miles north of these outcrops, mafic pillow lavas and breccias occur at a similar stratigraphic level, thus implying that deposition of these units occurred in a submarine setting. Immediately to the northwest (100 m) are outcrops of dark gray to black spherulitic flow-layered lavas. The spherulites in these units stand out as flattened oblate spheroids in a glassy devitrified groundmass containing widely disseminated phenocrysts of plagioclase. It is uncertain if the felsic and mafic units are consanguineous eruptive phases or if the felsic unit is intrusive into the mafic pyroclastic unit.

Return to vehicles and continue to top of topographic ridge on pasture road. Exit vehicles and proceed on foot to barn at top of ridge adjacent to high voltage powerlines. Stop first at the outcrops immediately to the east of the barn, then continue north under the powerlines to hilltop 300 m to the north. This is the last unit to be examined on this portion of the field trip.

Mafic tuff breccias at the first outcrop consist of subangular to rounded blocks (up to 0.5 m dimension) of laminated felsic crystal tuff, gabbro, and felsic porphyries in a matrix of mafic lapilli (1 to 5 cm in size). The mafic tuff breccias are attributed to subaqueous phreatic eruptions in which lithified units are incorporated in the eruption column as exotic blocks. Felsic units to the west consist of spherulitic flow-layered lavas and rather extensive outcrops of a crystal rich, vitric lapilli tuff. The lapilli crystal tuff contains subordinate vitriclasts (size less than 2 cm) in a matrix of plagioclase and quartz crystals. Lithic clasts in the pyroclastic units include spherulites, felsic porphyries and rarely mafic lavas. Stratification is not evident at this locality although similar units to the west are horizontally stratified and grade into laminated vitric tuffs, containing convolute laminae (dewatering structures). These depositional units are interpreted to be sediment gravity flows emanating from subaqueous eruptive centers. However these flow units are not doubly graded, a point substantiated by Seiders and Wright (1977). One other unique feature of these units is the paucity of pumice. Cas (1983) inferred that crystal rich pyroclastic flow units may be a function of 1) the near complete crystallization of the eruptive magma chamber and 2) elutriation of fines (ash and pumice) in the eruption column with secondary enrichment of crystals by phreatic explosions in the hot pyroclastic flow as it enters cooler water.

The felsic and mafic rocks exposed at this locality are interpreted to overly the Hyco Formation. These map units also match those lithologies mapped by Seiders (1978, 1981) in the adjacent Asheboro 15' guadrangle. It is possible that a fault could separate the major stratigraphic units in the immediate area, although present field data and mapping has not delineated the occurrence of a major detachment horizon.

GEOLOGY OF THE VIRGILINA AREA

The geology of the type area of the Virgilina deformation is shown on Figure 7 which was compiled from geologic mapping by Glover and graduate students at Virginia Tech. Pioneering work by Laney (1917) is incorporated into this map and the basic stratigraphic nomenclature is only slightly modified from his. Laney's map and report on the Virgilina District is a classic example of an outstanding field study from the early part of this century and it has continuing utility in furthering our understanding of the region today. Another excellent detailed map by Kreisa (1980) adjoins Figure 7 to the north. Other pertinent maps and studies in the area include Conley and Bain (1965), Allen and Wilson (1968), Tobisch and Glover (1969), Tobisch and Glover (1971), Glover and Sinha (1973), Hadley (1973), Wright (1974), Conley (1978), McConnell and Glover (1982), and Newton (1983).

Hyco Formation

The Hyco Formation is at least 4900 m thick and is composed dominantly of rhyodacitic to andesitic pyroclastic rocks, shallow intrusives and lavas. Less abundant compositions include rhyolite and high alumina basalt. Chemistry is given in Kreisa (1980) and Newton (1983). Several studies reviewed by Rogers (1983) show the Hyco to be part of a magmatic arc of calc-alkaline affinity.

North of the area in Figure 7 the Hyco is felsic (Kreisa, 1980), greenstone appears at the top of the formation near the Virginia-North Carolina state line and to the south, southwest and southeast of Roxboro, NC andesitic rocks are abundant (Glover and Sinha, 1973; Wright, 1974; McConnell and Glover, 1982; Newton, 1983).

Subvolcanic intrusive rocks are abundant throughout the Hyco and are most abundant in the lower part of the Formation. One of these, the Flat River Complex (Figure 7), has been dated by the zircon U-Pb method at 650 $\pm$ 30 Ma (McConnell and Glover, 1982). The Flat River Complex represents a volcanic magma chamber now exhumed in cros section. [Wright (1974) and McConnell and Glover (1982) concluded that the Flat River was eruptive and produced the overlying dominantly pyroclastic Hyco sequence.] Newton (1983) continued this line of investigation in the Hillsborough and Efland guadrangles and presented evidence that a large cauldron formed this part of the Hyco between 650 Ma (age of the Flat River) and 620 Ma (age of the top of the Hyco from Glover and Sinha, 1973). Throughout the mapped vertical and lateral extent of the Hyco Formation coarse pyroclastic material and shallowly emplaced intrusive rocks are common. Thus a near-vent origin of the Formation is indicated. The map distributions of rock compositions within the Hyco also support the conclusions that magma composition varied within the same eruptive center (Wright, 1974; Newton, 1983) through time and that differing compositions probably were erupting coevally from adjacent centers.

Earlier investigation (Glover and Sinha, 1973) suggested a subaerial origin for much or all of the Formation in the Roxboro quadrangle. The major evidence for a subaerial origin was the discovery of red welded tuff with spherulitic crystallization textures in the upper Hyco. Subsequent mapping studies in our program (Wright, 1974; McConnell and Glover, 1982; Newton, 1983) have shown that most of the sequence is marine, perhaps deposited below storm wave base but probably not in thousands of feet of water.

Evidence for this is best summarized in Wright (1974) who records:

1. Scattered through massive units of poorly-to moderately-sorted lapilli tuff are thin bedded and locally delicately laminated well sorted and graded accumulations of fine to coarse tuff. These well sorted layers probably represent ash deposited directly into quiet water and sorted as a result of their varying settling velocities. Primary sedimentary features in some vertically graded tuffs include poor sorting, cross laminations, ripples and convolute laminations. These beds appear to be ash distributed by turbidity currents.

2. Many of these pyroclastic deposits appear to be moderately sorted, i.e. to contain between 10 and 25 percent fine fraction less than 2 mm in diameter. Thus they are better sorted than the shallow water deposits described by Fiske and Matsuda (1964), much better sorted than typical subaerial pyroclastics (Ross and Smith, 1961) which commonly contain more than 50 percent fine ash, but are much less well sorted than deep water pyroclastic rocks (Fiske and Matsuda, 1964). On sorting criteria the Hyco therefore probably

contains a lot of pyroclastic material deposited below storm base but not at great depths.

3. A few layers composed of long-tube pumice were found in the massive near vent accumulations of lapilli tuff and tuff. These also appear to represent sorting in a column of water (Fiske, 1963). This is because long tube pumice leaks and sinks while round bubble pumice floats away. Round bubble scoria would, be definition, sink but none was noted.
4. The Hyco contains Precambrian metazoan fossils (Cloud, et al., 1976) transported into the basin by turbidity currents. These also seem to confirm that a marine rather than fresh water environment was present.
5. The above characteristics are mutually exclusive of obviously subaerial parts of the Hyco that contain red and gray welded tuff, red oxidized lavas and red unstratified and unsorted pyroclastic debris.

The base of the Hyco is seen in the northwestern corner of the Roxboro quadrangle where it essentially coincides with the transition from greenschist facies in the slate belt to amphibolite facies in the Charlotte belt (Tobisch and Glover 1969). The underlying rocks include plagioclase-quartz-biotite-hornblende-(epidote) gneiss of probably volcanic parentage. The top of the Hyco in the eastern Roxboro quadrangle is probably a nonconformable contact of subaerial Hyco with conglomerate of the overlaying quiet water (moderately deep?) marine Aaron Formation.

The age range of the Formation is >650 $\pm$ 30 Ma to 620 $\pm$ 20 Ma (Glover and Sinha, 1973; McConnell and Glover, 1982).

The Hyco can be distinguished from the younger post-Virgilina sequence by the abundant andesite that it contains, and by major and minor element chemistry which indicate that the Hyco represents a mature magmatic arc of calc-alkaline affinities (op.cit, especially Rogers, 1982). A key field relation is that the Hyco is everywhere overlain by the easily identified Aaron Formation described below.

Aaron Formation

The Aaron Formation (Fig. 7) consists mainly of well stratified sandstone, siltstone, graywacke and mudstone with a conspicuous but minor amount of conglomerate and tuff. The Formation is between 900 and 1800 m thick. Kreisa (1980) elected to use Laney's (1917) definition of the Aaron which included the Virgilina Greenstone and overlying thin bedded sedimentary rocks. Without prejudice toward either nomenclature, for the purpose of this guidebook the subdivision of Glover and Sinha (1973) is continued as shown on Figure 7. By this treatment Kreisa's middle and upper members of the Aaron Formation herein remain the Virgilina Formation and include the Virgilina Greenstone of Laney with interleaved and overlying thin bedded sandstone and mudstone.

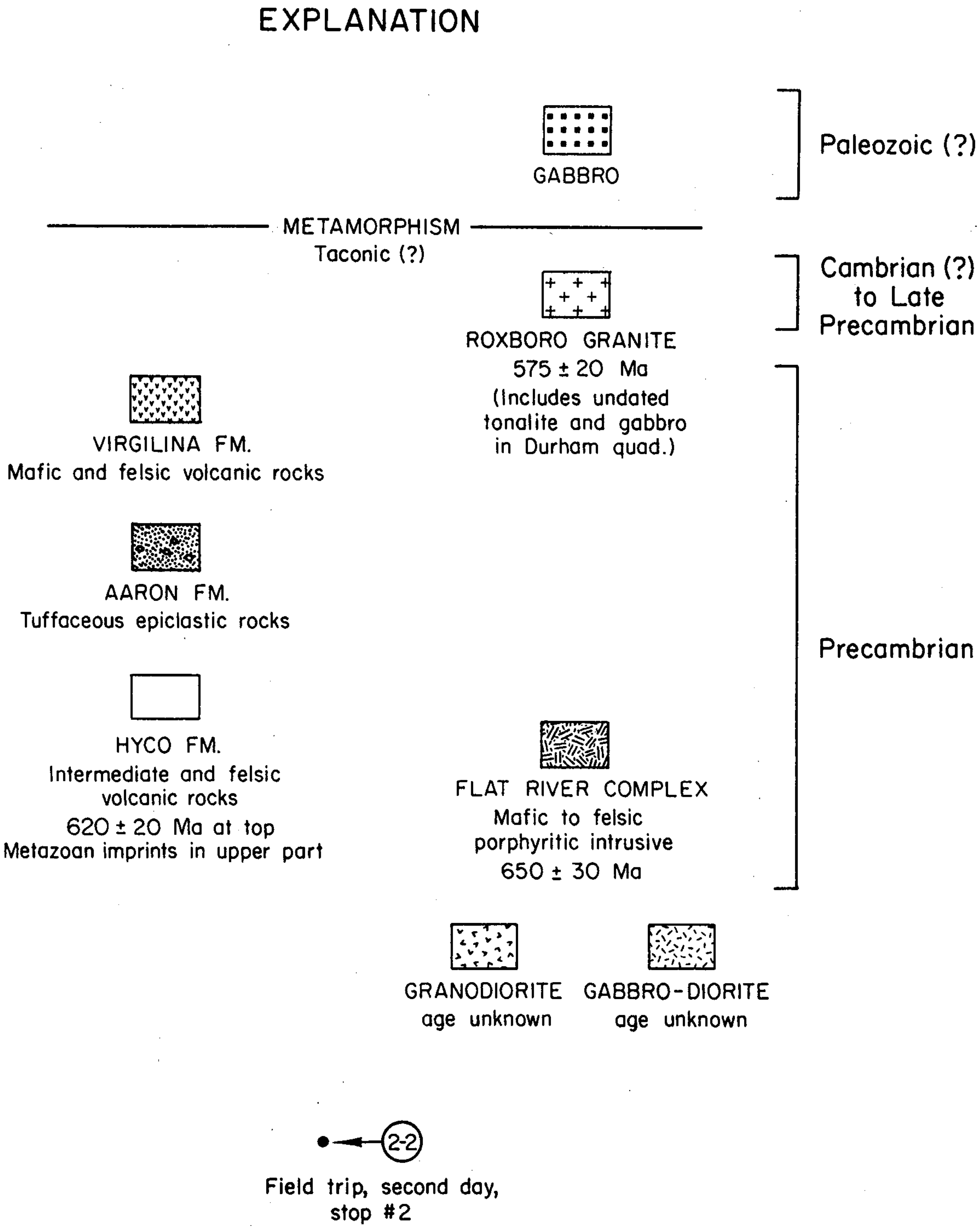
Bedding in the Aaron varies from laminae and beds of a centimeter or so in thickness to beds of more than a meter in thickness. Cross bedding and ripple lamination appear to be rare. However such small sedimentary structures may be partly obscured by the deeper weathering and more intense metamorphic deformation in the Roxboro-Virgilina area when compared with outcrops in central North Carolina. More generally one finds horizontally stratified sandstone, siltstone and mudstone in greatest abundance. Less common are 5 – 10 cm graded bids of sandstone overlain by thin beds or laminae of fine siltstone and sandstone capped by claystone or mudstone.

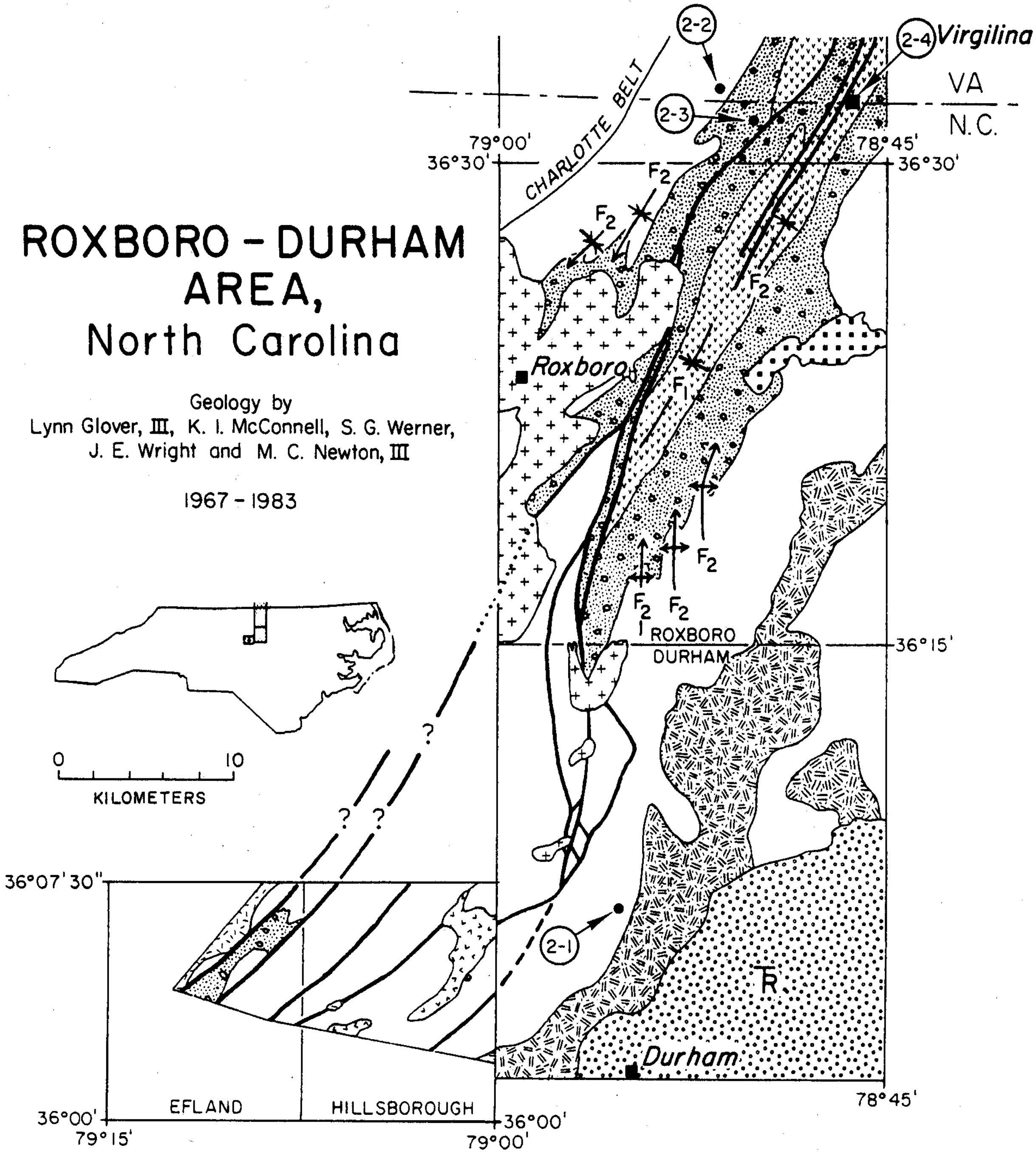
Conglomerate is by volume less than a few percent of the Formation but it is a conspicuous lithology. Both clast supported and matrix supported conglomerate occur at and above the base of the Formation. Many conglomerate outcrops lack internal stratification and appear to be debris flows emplaced in a quiet and probably deep water turbidite-bearing sequence.

Thin sections of the sands reveal rounded grains of quartz, feldspar, fine grained volcanic fragments, intraformational clasts and muddy indeterminate matrix. Most of the material appears to have been eroded from uplifted areas of the underlying Hyco Formation. Most revealing are the conglomerate clasts. These comprise: 1) felsic and intermediate volcanic clasts similar to lithologies in the Hyco, 2) granitoid clasts from somewhat porphyritic subvolcanic intrusive rocks, 3) vein quartz pebbles, 4) abundant quartz arenite pebbles and cobbles. One of these quartz arenite cobbles in Glover's collection is about 30 cm in diameter and has cross-bedding defined by heavy mineral concentrations along foreset and planar bedding surfaces.

Although minor amounts of pyroclastic materials occur within the Aaron, most of the Aaron is the product of erosion of an older and somewhat consolidated terrane that probably had continental basement exposed to furnish the quartz arenite cobbles. Thus the Aaron is considered to be a largely epiclastic deposit laid down on the older calc-alkaline magmatic arc during a time of diminished volcanic activity. Folding and/or faulting are assumed to have produced the high and low areas that are required for source regions and basin of sediment accumulation. Possibly this tectonism was the beginning of the Virgilina deformation.

The Aaron, with its persistent bedding and its quartz arenite pebble-bearing conglomerates, is a conspicuous unit (Fig. 11, Appendix) in the Carolina slate belt. It has been traced in continuous unbroken succession from about 10 miles SE of Farmville, VAto a point 10 miles south of Roxboro, NC, a distance of 80 miles. In discontinuous outcrop it can be recognized in several areas from there to a short distance southwest of Chapel Hill where a continuous belt extends into the Ramseur area. Thus the Formation maintains a remarkable similar lithology over a known strike distance of 150 miles. The Aaron differs from the Tillery


EXPLANATION
GABBRO
Paleozoic (?)
METAMORPHISM
Taconic (?)
ROXBORO GRANITE
575 ± 20 Ma
(Includes undated tonalite and gabbro in Durham quad.)
Cambrian (?) to Late Precambrian
VIRGILINA FM.
Mafic and felsic volcanic rocks
AARON FM.
Tuffaceous epiclastic rocks
Precambrian
HYCO FM.
Intermediate and felsic volcanic rocks
620 ± 20 Ma at top
Metazoan imprints in upper part
FLAT RIVER COMPLEX
Mafic to felsic porphyritic intrusive
650 ± 30 Ma
GRANODIORITE
age unknown
GABBRO-DIORITE
age unknown
2-2
Field trip, second day, stop #2



ROXBORO - DURHAM AREA,
North Carolina
Geology by
Lynn Glover, III, K. I. McConnell, S. G. Werner, J. E. Wright and M. C. Newton, III
1967 - 1983
KILOMETERS
0
10
Virgilina
VA
N.C.
CHARLOTTE BELT
Roxboro
ROXBORO
DURHAM
Durham
EFLAND
HILLSBOROUGH
2-1
2-2
2-3
2-4
79°00'
36°30'
78°45'
36°15'
36°07'30"
36°00'
79°15'

Figure 7.

Formation, with which it was correlated by Wright and Seiders (1980), in the abundance of epiclastic material, and especially in the quartz arenite pebbles that it contains.

Virgilina Formation

The Virgilina Formation comprises at least 1000 m of dominantly basaltic pyroclastic rocks, volcanic breccias and sills which, south of the Virginia-North Carolina line, are locally intercalated with and overlain by felsic pyroclastic rocks and sills. The lower contact is formed by interleaving of Aaron sandstones with basaltic breccias. At the top of the Pyroclastic rocks basalt and felsic volcanics grade upward abruptly into a hundred meters or more of thin bedded to laminated greenish gray mudstone which is truncated by the present erosion surface.

Basalt occurs as sills, and as massive, coarsely vessiculated tuff breccia; possibly as hyaloclastic quench breccias; also as lapilli tuff and thin-to medium-bedded fine to coarse tuff. A chemical analysis is given by Bland (1978). No analyses exist for the felsic rocks, but they resemble the dacites of the Hyco Formation. Coarse vessiculation may indicate a relatively shallow depth of emplacement. On the other hand, no shallow water features were observed so a depth below storm wave base is assumed. A similar environment may also be appropriate for the uppermost laminated to thin, locally graded bedded mudstone.

The Roxboro Metagranite and the Virgilina deformation

The Roxboro is a microphaneritic granite with phenocrysts of plagioclase, perthite and quartz, accompanied by biotite, opaque minerals and porphyroblasts of epidote. Locally a granophyric groundmass is present (Briggs and others, 1978). Based on the composition of the granophyre, the pluton was emplaced at a pressure of about 350 bars (1 km depth), nearly dry and at a temperature of about 950^{o}C (Briggs and others, 1978). The Roxboro was dated by the zircon U-Pb isotope method and found to be 575 $\pm$ 29 Ma (Glover and Sinha, 1973). The Roxboro clearly intruded a sequence younger than 620 $\pm$ 20 Ma (upper Hyco age) that was already deformed by the Virgilina deformation (Figures 7 and 8). Thus the age of the Virgilina deformation is bracketed between about 620 Ma and 575 Ma. In relative time terms this is latest Precambrian (Eocambrian).

The shallow depth of emplacement and granophyric texture indicate that the granite itself represents a fossil magma chamber from which a post-Virgilina volcanic sequence erupted. Briggs and others (1978), following Glover (1974), suggested that such a volcanic sequence would be 575 Ma and younger and would rest unconformably upon the pre-Virgilina deformation sequence. They suggested that the younger sequence was eroded from the Virgilina area but still existed in the Albemarle area of central North Carolina.

Structural Geology and the Virgilina deformation

The structure of the Roxboro area is discussed in some detail in Glover and Sinha (1973) and is shown here in figures 7 and 8. Figure 8 gives more detail in terms of map evidence but does not illustrate the full amount of control (more than 2800 observation stations in the Roxboro 15'’quadrangle) for the contact relations.

From Figures 7 and 8 it can be seen that the $_1$ phase of the Virgilina synclinorium is younger than the 620 $\pm$ 20 Ma upper Hyco Formation. F_1 is also older than the faulting and the faulting is older than the 575 $\pm$ 20 Ma Roxboro Metagranite.

In order to explain the distribution of Hyco and Aaron around the Roxboro Metagranite another pre-intrusive fault could be drawn as a dotted line (covered contact) through the granite. This pre-intrusive fault would be drawn in a southwestward direction from the fault that is truncated at the northeastern edge of the granite, and it would continue through the town of Roxboro and beyond. Note also that the Roxboro and several other intrusive bodies to the south of the Roxboro appear to have been guided in their emplacement by pre existing faults.

Left lateral transcurrent faulting to offset the F_1 axis of the Virgilina synclinorium was proposed by Glover and Sinha (1973). In the light of subsequent mapping Glover now prefers to view most these faults as high angle reverse. They may have developed in order to solve the room problem in the core of the Virgilina synclinorium as folding progressed. Faults that truncate the F_1 axis may have some left lateral motion on them where they serve to accommodate transfer of motion between east dipping faults on the west limb of the synclinorium. In other words, the axis of the Virgilina synclinorium may not be offset at all, rather the older and deeper stratigraphy in the core of the synclinorium may have simply been raised in an upward widening fault block as folding progressed. However, this suggested structure is not in agreement with Newton (1783), who views apparent extensions of this fault system in the Hillsboro and Efland quadrangles as cauldera-generated faults of the age of the Hyco. These uncertainties do not change the basis for the Virgilina deformation in the type area.

After the emplacement of the Roxboro Metagranite the terrane was metamorphosed and deformed. Because there is no evidence for metamorphism during the Virgilina deformation, the first cleavage (S_1) is associated with F_2 folds. S_1 cleavage is parallel to the N30^{o}W trending F_1 Virgilina synclinorium axis in the northern part of the Roxboro quadrangle. Southward the S_1 cleavage swings to a NS orientation and cuts across the limb of the F_1 fold (Fig. 8). In doing so the D_2 deformation refolded the SE limb of the synclinoriu into several large F_2 folds as shown on Figures 7 and 8. The metamorphism produced lower greenschist facies rocks over all but the northwestern quarter of the Roxboro quadrangle (Fig. 7) where metamorphic grade increases to amphibolite facies at the Charlotte belt boundary (Tobish and Glover, 1969; Glover and Sinha, 1973). The age of the metamorphic is believed to be Late Ordovician, Taconic (Kish, and others, 1979; Glover, and others, 1983)

FIELD TRIP STOPS IN THE VIRGILINA AREA, DAY 2

There are four field trip stops on the second day which are geographically located on Figure 9a and 9b. The geological setting of each stop is given on Figure 7.

Stop 2–1. Hyco Formation; map unit Al of Wright (1974). This part of the Hyco is predominantly massive andesitic coarse tuff and lapilli tuff with minor amounts of tuff breccia and bedded tuff. Only a small amount of the sequence is fine grained and well bedded. That which is fine grained commonly is laminated to thin bedded and normally graded. Locally the fine grained material may have cross laminations or ripples and show soft sediment slump and pull-apart structures.

The pyroclastic debris has four basic forms: lithic, crystal, pumice, vitric and vitric crystal fragments. For reasons discussed in the text this unit is believed to have been deposited in a marine environment below storm wave base.

The principle reason for stopping here is to examine what has been mapped as andesitic pyroclastic material in the Hyco of the Virgilina-Roxboro-Durham area for comparison with andesitic rocks from the Hyco Formation in the Ramseur area. The andesitic composition of rocks in this area have been confirmed by chemical analyses in Newton (1983). Rocks of this composition are common in the pre-Virgilina deformation sequences but appear to be absent in the post-Virgilina sequences.

From stop 201 go north on U.S. 501 to the Virginia-North Carolina State line. This places you in the vicinity of Stops 2-2 to 2-4 shown on Figure 9b.

Stop 2-2. Hyco Formation at the Christie, Virginia railroad cut. Felsic pyroclastic facies of the Hyco Formation are abundantly exposed here. Bedded tuff and lapilli tuff with crystals of quartz and plagioclase and locally a few beds of intermediate pyroclastic rock can be found in this facies. Sills of basalt are common and may be feeder dikes to the Virgilina greenstones near the top of the older sequence. This lithology is overlain by intermediate to mafic pyroclastic rocks near the top of the Formation 0.4 mi. east of this cut.

At this stop we are only a few miles east of the Charlotte belt. Notice that the rocks here are more deformed than those in our previous stops. Tobisch and Glover (1969, 1971) and Kreisa (1980) determined that the western boundary of the Carolina slate belt near here is primarily a metamorphic facies change to higher grade rocks.

The upper part of the Hyco has a zircon U-Pb isotopic age of 620 $\pm$ 20 Ma (Glover and Sinha, 1973). It is overlain by the Aaron Formation which will be seen at Stop 2-3. Compare the Hyco and Aaron in this area with that seen near Ramseur. See the difficulties of correlating these rocks with Uwharrie and Tillery as Wright and Seiders (1980) suggested.

Stop 2-3. See Figure 10

Stop 2-4. Optional Stop.

Virgilina greenstone type locality of Laney (1917). Basaltic tuff, lapilli tuff, tuff breccia, and basalt sills (?) or lava flows (?). Outcrop may not be very accessible. Since the railroad tracks were taken up the local people have attempted to block the roadbed from recreational vehicles, and the outcrop has also grown up with vegetation.

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EXPLANATION

Upper Precambrian or Cambrian (?)

4
ROXBORO GRANITE

Upper Precambrian

IV
VIRGILINA FM.
Mafic and felsic volcanic rocks

III
AARON FM.
Tuffaceous epiclastic rocks

II
HYCO FM.
Felsic and intermediate volcanic rocks

Contact

U
D
Fault
U, upthrown side; D, downthrown side.

F_2
Anticline

F_1
Synclinorium

27
Bearing and plunge of minor fold (all F_2)

Trace of axial plane of fold and direction of plunge
Value of plunge given where known
F_1, first fold phase F_2, second fold phase

70
Inclined

90
Vertical

65
Overturned

Strike and dip of beds
Ball indicates top known from graded beds
Position of 90 on vertical beds indicates top direction

80
Inclined

Vertical

Strike and dip of cleavage (schistosity)

A_1 A_2 B C
Separate structural blocks bounded by faults

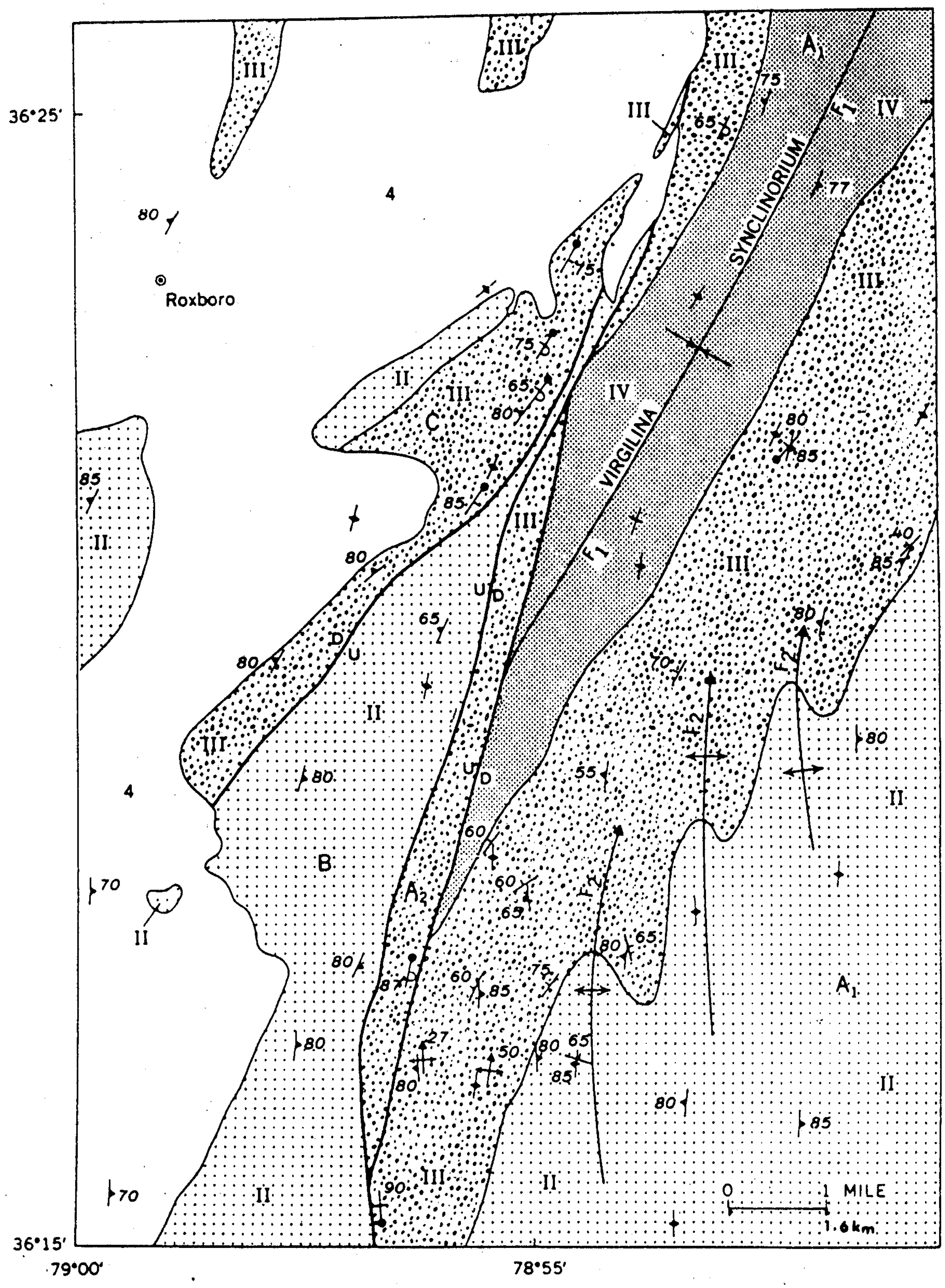

Figure 8: Geologic map of southwestern Roxboro, N.C. 15' quadrangle. Modified from Glover and Sinha, 1973.

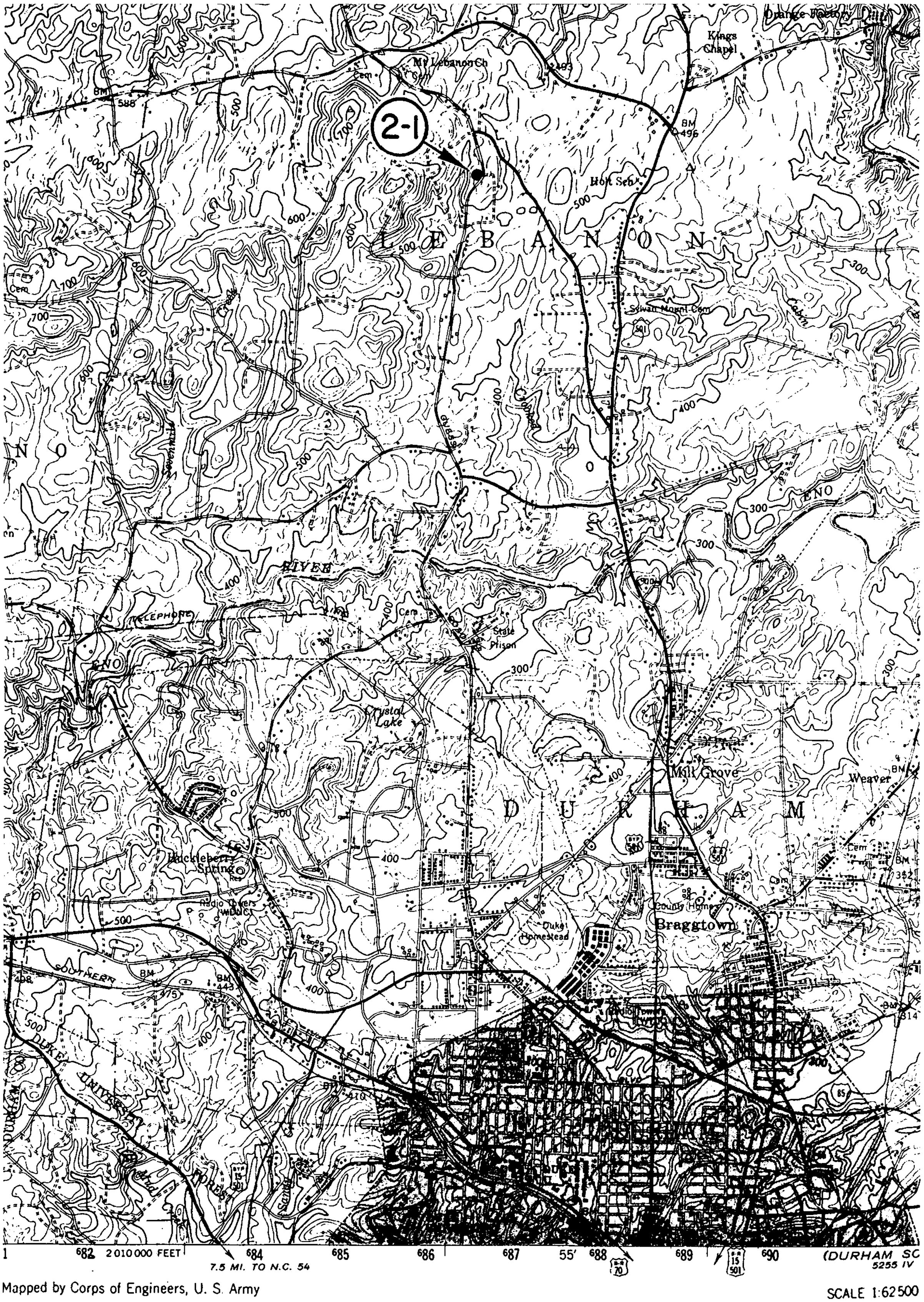

Figure 9a: Trip stop 1, second day.

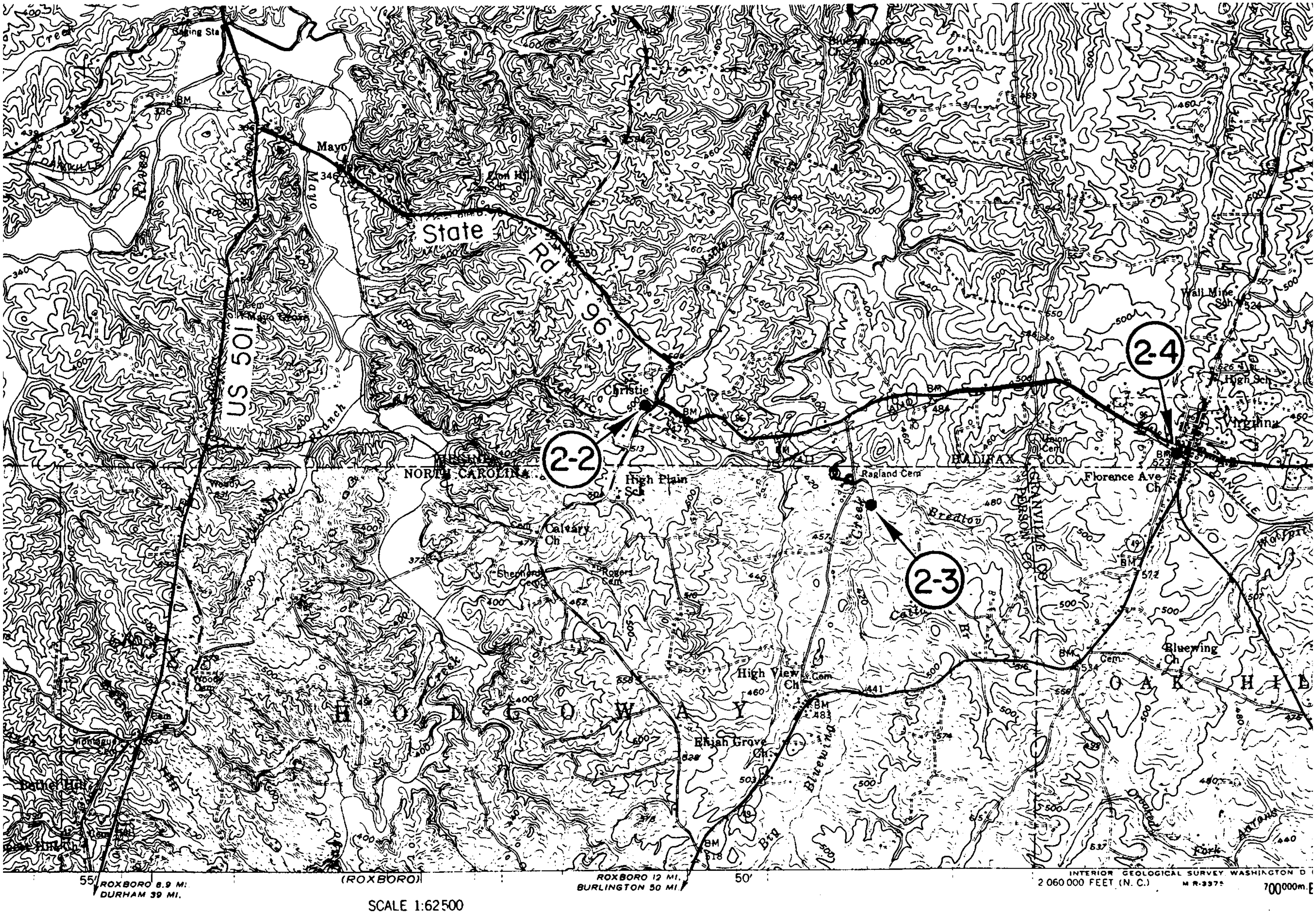

Figure 9b: Location of stops near Virgilina, second day.

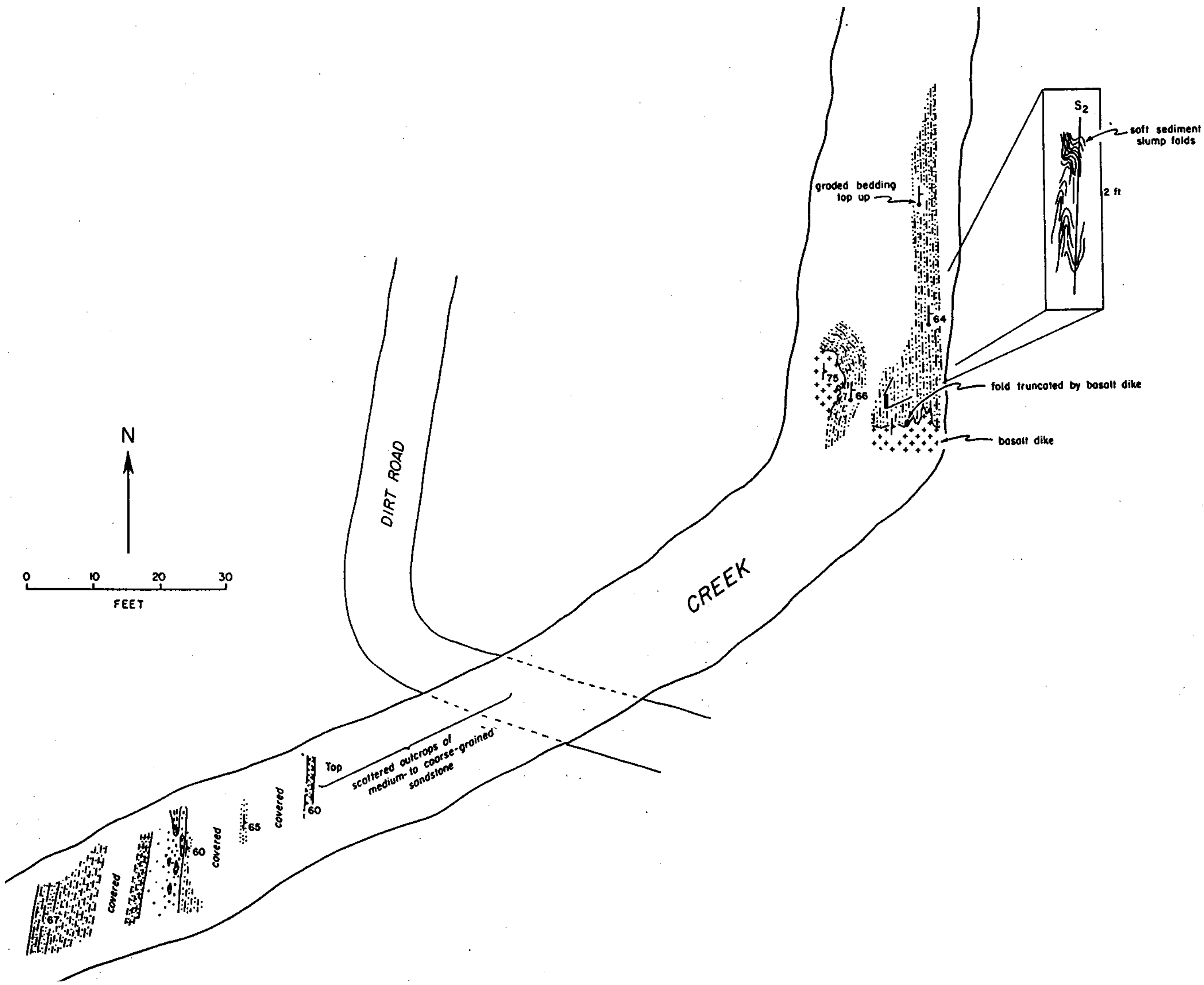

Figure 10: Stop No. 2-3

Aaron Formation (map unit III of Glover and Sinha, 1973). Outcrops in stream consists of fine-to coarse-grained graywacke nd mudstone. Bedding varies from 5mm to 30cm in thickness. Graded sandstone beds are interleaved with claystone/mudstone layers without associated laminated or rippled beds that would accompany a complete Bouma sequence. Thus these beds appear to be T, a, d, e in conventional turbidite terminology. Soft sediment slumping occurred in the eastern outcrops. Conglomerate occurs southwest of the road in a bed approximately one meter thick. Clasts consists of pebbles of volcanic rock and pebbles of quartz and quartz-arenite. Larger rip-up or pull-apart clasts of intraformational sandstone are also present in sizes from a few centimeters to over a meter. The conglomerate bed has no internal stratification and is interpreted to be a debris flow deposited in a quiet (deep?) water environment where turbidites and minor pelagic sedimentation accumulated. A basalt dike intruded the eastern outcrops and may have been a feeder dike to the overlying Virgilina Greenstone of Laney (1917).

Description by Lynn Glover, III and Judith Paterson

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APPENDIX

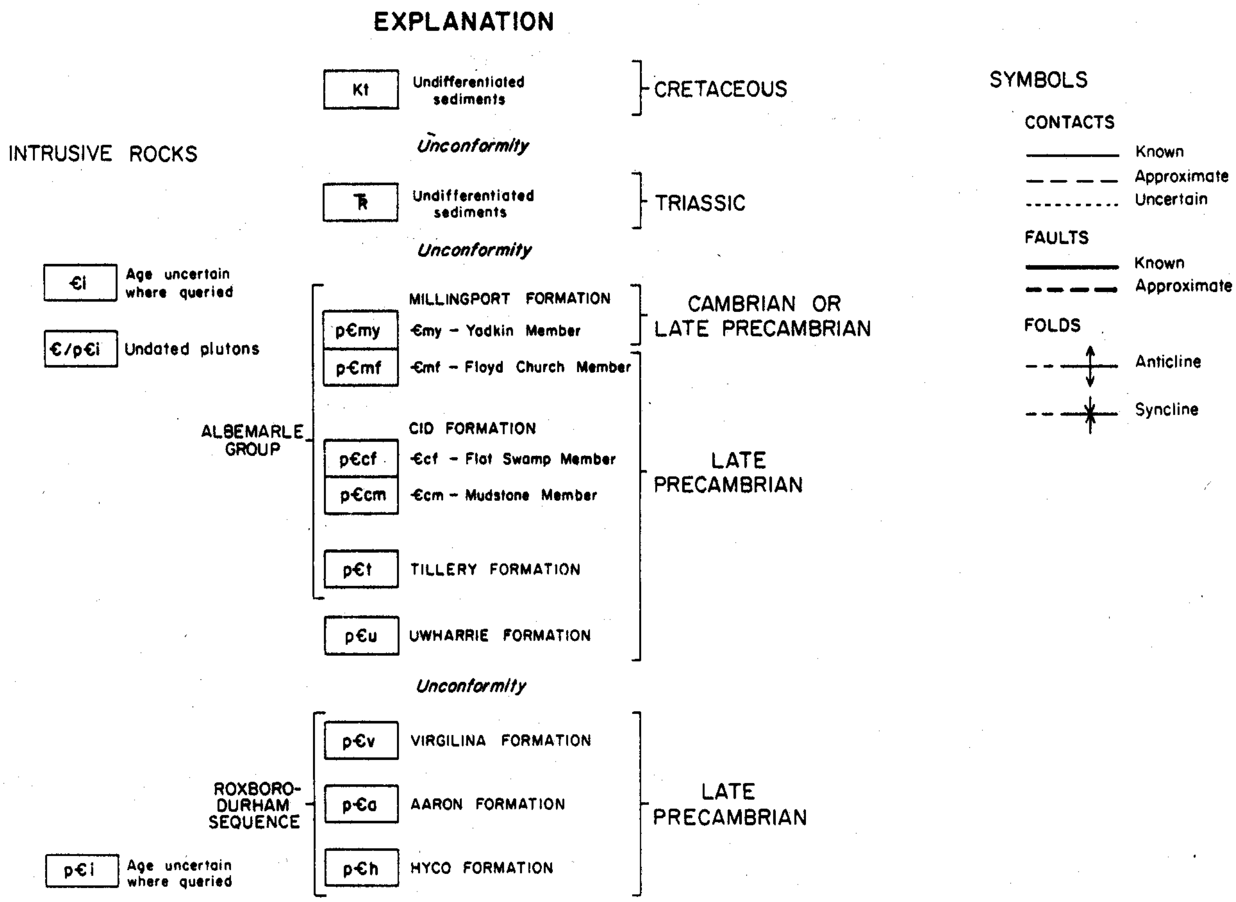
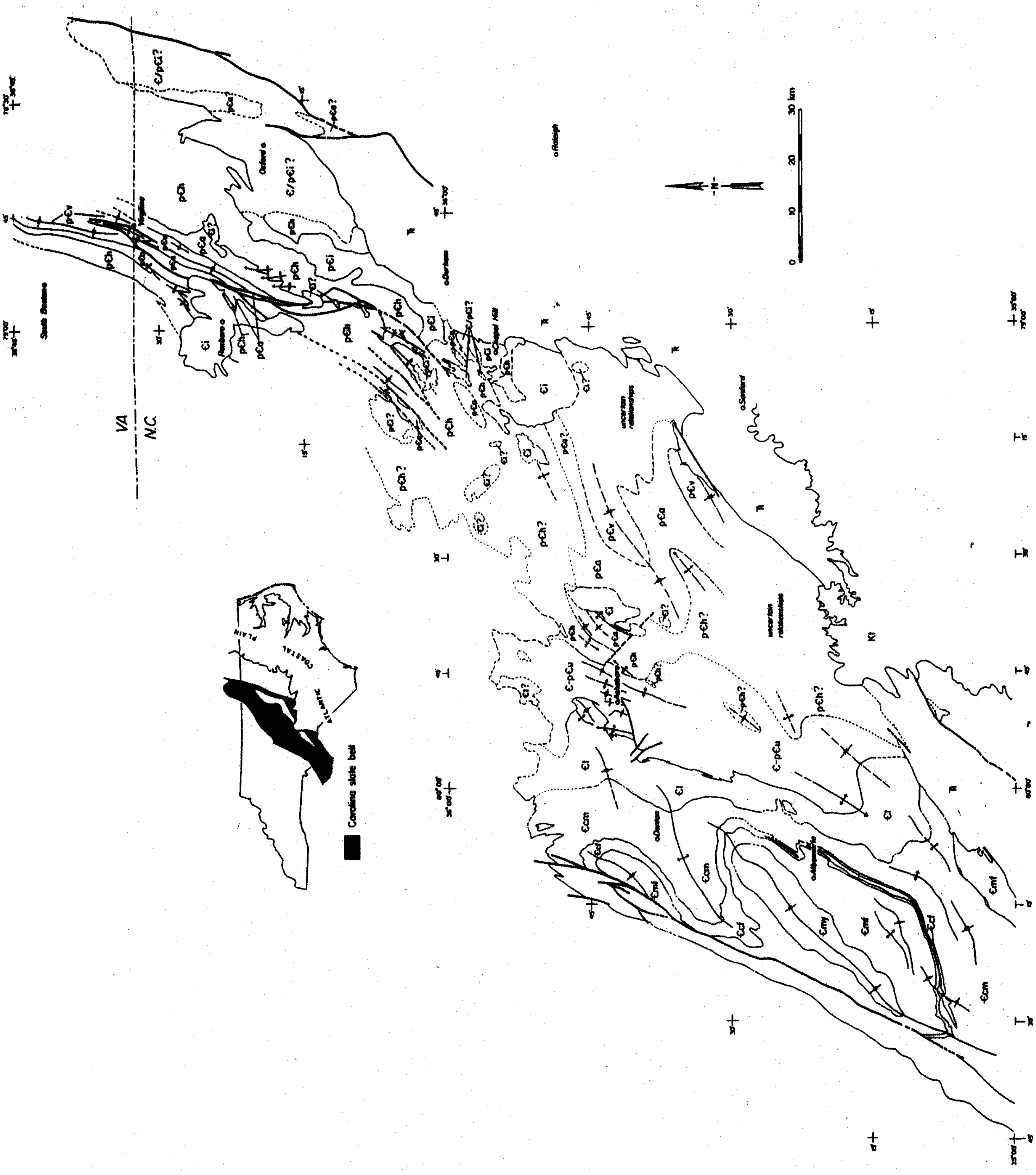
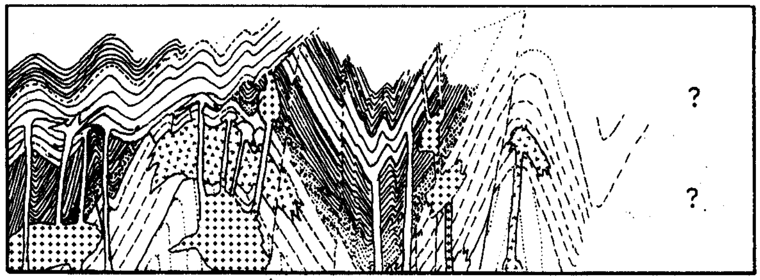


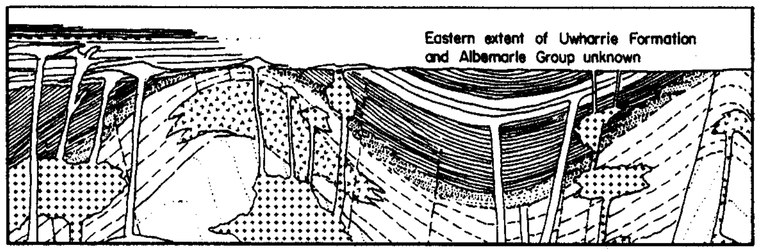
Figure 11: Regional geologic map of the Carolina slate belt. (Note: does not include Eastern slate belt). Data compiled from Conley and Bain (1965); Stromquist and Sundelius (1969); Carpenter (1979, 1982); Smeds (1972); Glover and Sinha (1973); Hadley (1973); Wright (1974); Wilson and Carpenter (1975); Hauck (1977); Seiders(1978, 1981); Wilkinson (1978); Kreisa (1980); Wright and Seiders (1980); Fodor et al. (1981); Goldsmith et al. (1982); Green et al. (1982); McConnell and Glover (1982); Tingle (1982); Newton (1983).



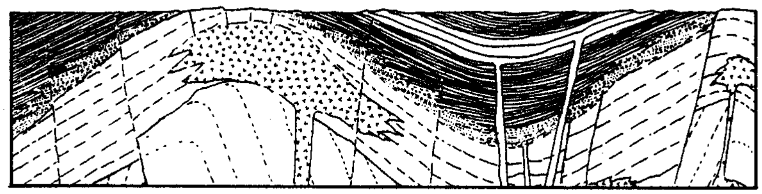
e. Early to Middle Ordovician ca. 480 to 440(?) Ma Taconic deformation and metamorphism of the entire volcanic-sedimentary sequence of the Carolina slate belt.



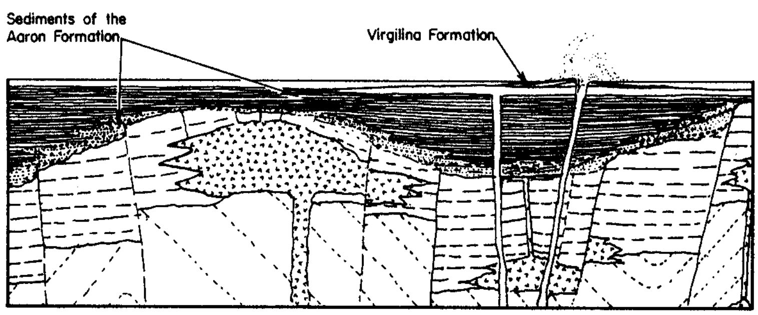
d. Late Precambrian to Middle Cambrian(?) ca. 590 to 540(?) Ma volcanism and sedimentation of the Uwharrie Formation and Albemarle Group accompanied by regional subsidence.



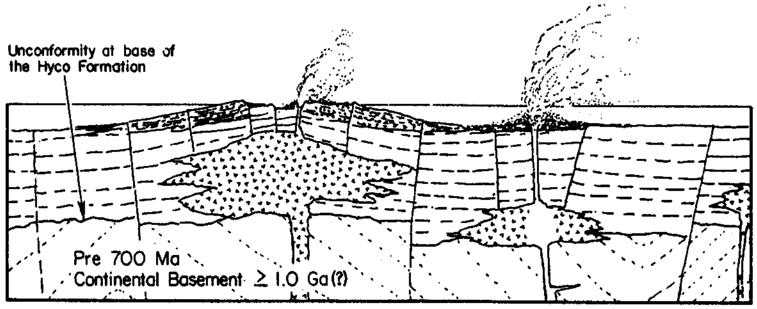
c. Late Precambrian ca. 600 to 590(?) Ma Virgilina deformation resulting in folding, faulting, uplift and concomitant erosion of the Virgilina sequence.



b. Late Precambrian ca. 620 to 600 Ma differential uplift and subsidence resulting in erosion of the Hyco Formation generating the retrogradational submarine fans of the Aaron Formation. Renewed volcanism is represented by the Virgilina Formation.



a. Late Precambrian, ca. 700 to 620 Ma, magmatic arc(?) of the Hyco Formation



Tectonic evolutionary scenario of the Carolina slate belt